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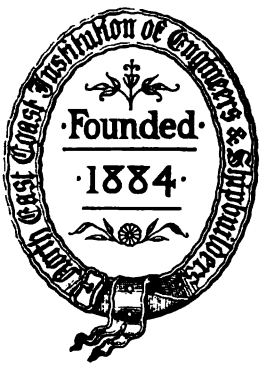

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NINTH SESSION, 1892-93.

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NAVAL ARCHITECTS, *Vol.* XXXIII., 1892.—Recent Progress in Warship Construction. On the Alterations in the Types and Proportions of Mercantile Vessels. Centre and Wing Ballast Tank Suctions in Double-bottomed Vessels. Some Notes

on the History, Progress, and Recent Practice in Marine Engineering. Progress in Marine Engineering in the Mercantile Marine. On the Weak Points in Steamers carrying Oil in Bulk. On Divisional Watertight Bulkheads as applied to Steamers and Sailing Vessels. On Steadying Vessels at Sea. Notes on Recent Experiences with H.M. Ships. A Ram Vessel and the importance of Rams in War. Whaleback Steamers. On an Approximate Rule for the Vertical Position of the Centre of Buoyancy. On Balancing Marine Engines and the Vibration of Vessels. Notes on the Strength of Steamers. On the Transverse Stability of Ships and a Rapid Method of Determining it. Notes on Experiments with Inflammable and Explosive Atmospheres of Petroleum Vapour. On the Theoretical Effect of the Roe Rotation on Screw Propeller Efficiency. Performance of three sets of Engines belonging to the Second Class Cruisers recently added to H.M. Navy as calculated from the full Power Steam Trials. On Convenient Curves for Determining the most Suitable Dimensions for Screw Propellers. On some Additional Features in the Constant Notation used at the Admiralty Experimental Works.

NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS, *Vol.* XXXIX., 1889-90.—Winding, Banking Out, and Screening Plant, at East Hetton Colliery. Memoir of E. F. Boyd. Improved Coal Screening and Cleaning. A New Mechanical Device for the Rapid Fixing of Surveying Instruments. The Hauraki Gold Mining District, N.Z. Ramsay's Patent Improved Levelling Staff for use in Mines. On the Value of Photography to Mining Engineers. Ancient Washes in the Coal-measures. The Economical Working of Steam Boilers at Collieries. On the Cleveland and South Durham Salt Industry. *Vol.* XL., 1890-91. —Experiments with Explosives in Mines. On the Bending of Beds near Veins. Some Banket Deposits of the Gold Coast. Experiments with Carbonite. The Steam Loop and Separator. The Waddle Patent (1890) Fan. Notes on the Present Position of the Question of Transmission of Power. Memoir of E. F. Boyd. Pumping Appliances at Eltringham Colliery. Fire-damp Detector. On a Duplex Arrangement of Centrifugal Ventilating Machines. *Vol.* XLI., 1891-92. Memoir of T. W. Bunning. Experiments with Explosives. Notes on the Products and Temperature of Detonation of some High Explosives. Memoir of John Marley. Description of a Method of Removing Deposits from the Inside of Rising Main Pipes in Shafts. The Lee Alarm Water-guage. The Robert Shot Firing Lamp. Notes on an Electric Transmission Plant at East Howle Colliery. The Practical Transmission of Power by means of Electricity and its Application to Mining Operations. Notes on the Gases enclosed in Coal and Coal-dust. An Enquiry into the Cause of the Two Seaham Explosions, 1871 and 1880, and the Pochin Explosion, 1884. The Rateau Ventilator. On Lightning in New Zealand Mines. Notes upon the Mines in the Argentine Republic, South America. The Witwaterstrandt Gold-field. The König Differential Water-guage. A Safety Appliance for Preventing Risk of Explosions in Mines. The Detonation of High Explosives by Percussion. The Hæmatite Ores of Cumberland. The Iron Ores of Spain. Geology of the Coal-field of Northumberland and Durham. The Tees Sea Salt Industry. The Ordnance Maps. The Electric Transmission of Power and its Analogies in Hydraulics. Notes on the occurrence of Manganese Ore near the Arenigs, Merionethshire, and near Mulegè Baja, California.

NOVA SCOTIAN INSTITUTE OF SCIENCE, Session 1890-91, *Vol.* I., *Part* 1.—Experiments on Nova Scotian Building Stone. Occurrence of Paraffin, Tallow, and Petroleum in Nova Scotia. The Magdalen Islands. Specific Gravity and Absorption of Building Stone from Nova Scotia and New Brunswick.

PHILOSOPHICAL SOCIETY OF GLASGOW, 1891-92, *Vol.* XXIII.—Limes and Cements. How our Bones Grow. The Scientific Cultivation of the Senses. The Sewage Problem in Villages and Small Towns. Women's Wages. Progress of School Building in Glasgow. The Rural Economy of Scotland in the time of Burns. On the First Edition of the Chemical Writings of Democratres and Synesius. The Origin of the Faust Legend. On Telephone Switch Boards. Warming and Ventilation of Public Buildings. Manufacture of Oxygen by Brins' Process. Some Elementary Facts Regarding the Foci of Lenses. On the Cause of the Spread of Pulmonary Consumption and other Tubercular Diseases. Fogs. Also Index, *Vols.* I. to XX.

ROYAL DUBLIN SOCIETY. PROCEEDINGS, *Vol.* VII., *No.* 3, March, 1892.—The Newly Hatched Larvæ of Euphyllia. Reports on Zoological Collections made in Torres Straits. Improvements in Lighthouse Lights. On a New Genus of Palæozoic Echinoids. Callesitics of *Nilophyllun Verselolor* on Preparing Schezonnycites, etc. Structure and Origin of the Quartzite Rock near Dublin. Lunar Radiant Heat. Slugs of Ireland. On Shutters for Use in Stellar Photography. On the Spectra of Gases. Analysis of the Spectrum of Sodium. Survey of the Fishing Grounds, West Coast of Ireland. *Part* 4, June, 1892.—Survey of Fishing Ground, West Coast of Ireland.

ROYAL DUBLIN SOCIETY. SCIENTIFIC TRANSACTIONS, *Vol.* IV., *No.* 9, July, 1891.—Lunar Radiant Heat. *No.* 10.—Slugs of Ireland. *No.* 11.—The Caùse of Double Lines in the Spectra of Gases. *No.* 12.—A Revision of the British Actinea. *No.* 13, *Part* 2.—Reports on the Zoological Collections made in Torres Straits. Actinea. I. Zoanthese.

SOCIÉTÉ DES INGÉNIEURS, Liége, Annuaire, *Tome* V., *No.* 3, 1892.—Sur quelque decouvertes recestes relatives aux courants alternatifs. La Russie industrielle. Note sur la fabrication de l'acies for the procede Thomas et Gilchrist. *No.* 4.—Les Ventilateurs de Mines. La prevention de accidents du travail dans les usines et les manufactures. *No.* 5.—Les soupapes de surete perfectionnees pour chandieres a vapeur. Les progas recents de la photographe.

L'ASSOCIATION DES INGÉNIEURS, Annuaire, *Tome* VI., *No.* 1, 1893.—La Russie Industrielle. Note sur un Nouveau Système de Graissage de Fusées d'essieux. Etudes Statistiques sur les Chemins de Fer. Note sur le Calcue des Fonds de Reservoirs Soutenus au Pourtour et au Centre. Annuaire, *Tome* VI., *No.* 2, 1893.—Sur la Rupture d'un Volant. Note sur les Nouveaux Planchers en Acier Dosen et Séton de Ciment. Note sur une Nouvelle Lamp de Mines. Note sur des Essais sur les Fontes de Cylindres de Locomotives les Clements Scientifiques de l'Assurane Contre les Accidents. Bulletin, *Tome* XV., *No.* 3, Mai-Juin, 1892.—Process Verbaux. *Nos.* 4 and 5, July and Oct., 1892.—Assemblee generale de L'Association de Ingénieurs sortis de L'École de Liége. No. 6, Nov.-Dec., 1892.—Excursions, etc. Bulletin, *Nos.* 1 and 2, 1893.—Proces Verbaux des Seances des Sections Liste des Membres. Bulletin, *Nos.* 4 and 5, 1893.—Sommarie Proces Verbaux des Seanes des Section. Necrologie Faits Divers, etc.

SOCIÉTÉ SCIENTIFIQUE INDUSTRIELLE DE MARSEILLE BULLETIN, *Vols.* I. to XIX., 1872-1891.

SOUTH WALES INSTITUTE OF ENGINEERS, *Vol.* XVIII., *No.* 1, 29 July, 1892.—The Bristöl Electric Safety-lamp. Note on the Coal-field of New South Wales. *No.* 2, Nov., 1892.—The Miner's Electric Safety-lamp. Safety Lock for Existing Miners' Lamps. The Miner's Piston Safety-lamp. Roofs of some of the Principal Seams of Coal in the Rhondda Valleys. *No.* 3, 1893.—Proposed New Dock for Cardiff. Screening and Cleaning Coal.

UNITED STATES NAVAL INSTITUTE, *Vol.* XVIII., *No.* 3, 1893.—First Aid to the Injured, and Transportation of the Wounded. *No.* 4.—Naval Signalling. Crusher and Cutter Gauges for Explosives. Pigeons for Sea Service. *Vol.* XIX., *No.* 1 (*No.* 65).—Automobile Torpedoes. The Chemical Analysis of the Three Guns at the U.S. Naval Academy Captured in Corea. Notes on the Literature of Explosives Naval Signalling. *No.* 2, 1893.—Practical Character of the Naval War College. Warships and Naval Warfare. The Van Duger-Mason Electric Steering Gear. The White Straight Pull Rifle. The Effect of Alteration of Propellers on the Speed of Vessels. Negative Reciprocal Equations.

PUBLICATIONS RECEIVED TO DATE, CURRENT NUMBERS OF WHICH LIE ON THE TABLES IN THE READING ROOM:

Electrical Engineer, 139, Salisbury Court, Fleet Street, London, E.C.
Electrical Review, 22, Paternoster Row, London, E.C.
Engineering, 35 and 36, Bedford Street, Strand, London, W.C.
Indian Engineer, 4, Dalhousie Square, Calcutta, British India.
Indian Engineering, Pat. Doyle, Esq., C.E., Spencer's Hotel, Calcutta, British India.
Industries, 358, Strand, London, W.C.
Iron and Coal Trades Review, 342, Strand, London, W.C.
Journal de la Marine le Yacht, 55, Rue de Châteaudun, Paris.
Marine Engineer, 3, Amen Corner, Paternoster Row, London, E.C.
Mechanical World, New Bridge Street, Manchester.
Rivista Marittima, Rome.
Shipping World, Effingham House, Arundel Street, London, E.C.
Stahl und Eisen, Düsseldorf.
The Steamship, 2, Custom House Chambers, Leith.
The Electrician, 1, Salisbury Court, Fleet Street, London, E.C.
The Engineer, 33, Norfolk Street, Strand, London, W.C.
The Engineering Review, 29, Great George Street, London, S.W.
The Practical Engineer, 6, Victoria Station Approach, Manchester.
The Illustrated Official Journal of Patents, Patent Office, London, E.C.
Transport, 35, Parliament Street, London, S.W.

LIST OF OFFICERS.

NINTH SESSION, 1892-93.

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R. L. WEIGHTON, M.A.
TOM WESTGARTH.

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Secretary and Treasurer:—JOHN DUCKITT.

Graduate Section:

President—R. L. GAINE.

Hon. Secretary—W. OXTON.

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NINTH SESSION, 1892-93.

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J. GRAVELL.
A. LAING.
HUGH MACOLL.
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Reading Committee:

J. GRAVELL.
M. HILL.
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W. G. SPENCE.
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Library Committee:

A. TAYLOR (Chairman).

C. A. CHRISTIE.
J. R. FOTHERGILL.
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P. D. WINSTANLEY.

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J. GRAVELL.
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J. F. WALLIKER.

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F. C. MARSHALL.
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Representative on Council of Durham College of Science:

JOHN GRAVELL.

Representatives on Sub-Committee of Northumberland County Technical Education Committee:

ALEXANDER TAYLOR.
GEORGE E. MACARTHY.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

List of Members, July, 1893.

EXPLANATION.

(A.)	Agent and Accountant.	(I. & S. M.)	Iron and Steel Merchants and Manufacturers.
(B. B.)	Boiler Builder.	(M. S.)	Marine Superintendent.
(C. E.)	Civil Engineer.	(N. A.)	Naval Architect.
(E.)	Engineer and Boilermaker.	(R. M.)	Rope Manufacturer.
(E. A.)	Engineering Agent.	(S.)	Shipbuilder.
(E. E.)	Electrical Engineer.	(S. O.)	Ship Owner.
(F. M.)	Forge Master.	(SUR.)	Engineer & Ship Surveyor.

HONORARY MEMBERS.

		ELECTED.
The Right Hon. Lord Armstrong, C.B., LL.D., F.R.S., Cragside, Rothbury		Nov. 1884
The Right Honourable the Earl of Ravensworth, Ravensworth Castle, near Gateshead-on-Tyne...		Nov. 1884
W. H. White, Esq., The Admiralty, Whitehall, London	(N A)	Nov. 1884

MEMBERS.

A.

Aberg, Henning, Stora Warfoet, Stockholm, Sweden	(E)	Oct. 1888
Abey, Henry, Fairfield, York Road, West Hartlepool	(E)	Jan. 1889
Adamson, Alex., c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness	(S)	Nov. 1885
Ahlbom, C.	(E)	Nov. 1884
Aitchison, Jas., Hylton, Sunderland	(S)	Nov. 1884
Alchin, A. H., Uxbridge Road, London, W.	(E)	Jan. 1885
Allan, Jas. McNeal, 3, Parkville, Heaton, Newcastle-on-Tyne ...	(E)	Dec. 1886
Allardes, Wm., c/o Messrs. Harland & Wolff, Ltd., Engine Works, Belfast	(E)	Nov. 1884
Anderson, Joseph, c/o Messrs. Wigham Richardson & Co., Neptune Works, Walker-on-Tyne	(E)	Nov. 1884
Andrew, D., 33, Osborne Road, Jesmond, Newcastle-on-Tyne ...	(SUR)	Jan. 1885
Andrews, Jas., Drawing Office, Messrs. Naval Construction and Armaments Co., Barrow-in-Furness	(E)	Nov. 1884
Angus, W. J., c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness	(E)	Oct. 1892
Anthony, Jas., 6, Northumberland Square, North Shields... ...	(S)	Oct. 1886

ELECTED.

Apolinaris dos Santos, J., Rio Grande-do-Sul, Brazil ... ...(SUR) Nov. 1891
Archbold, Joseph G., c/o Messrs. Blyth Dry Dock Co., Blyth ... (E) Jan. 1889
Armstrong, G. S., 37, Warwick Street, Heaton, Newcastle-on-Tyne (S) Nov. 1884
Armstrong, Joseph, 27, Ripon Street, Sunderland ... ... (S) Nov. 1892
Armstrong, Robert B., 26, Warwick Street, Heaton, Newcastle-on-Tyne ... ... (E) Oct. 1887
Arnison, Geo., Jun., 61, Fawcett Street, Sunderland (N A & SUR) Nov. 1884
Ash, Mortimer W., 91, Jesmond Road, Newcastle-on-Tyne ... (E) Feb. 1887
Atherton, William Henry, 71, Westmorland Road, Newcastle-on-Tyne... ... ... (E) Oct. 1891
Atkinson, F. C., 123, Croydon Road, Newcastle-on-Tyne ... ... (E) Dec. 1892
Atkinson, John Joseph, 7, Swiss Road, Elm Park, Fairfield, Liverpool ... ... (E) Mar. 1891
Austin, S. P., Wear Dockyard, Sunderland ... ... (S) Nov. 1884
Austin, W. R., Lloyd's Register of Shipping, Royal Exchange, Middlesborough ... ... (E SUR) Oct. 1888

B.

Baguley, Ernest Edwin, Lyndhurst, Rowley Park, Stafford ... (E) April 1891
Bailey, James, 3, South Avenue, Ryton-on-Tyne ... ... (E) Nov. 1884
Baines, Geo. Henry, Messrs. Central Marine Engineering Co., West Hartlepool ... ... (E) Oct. 1888
Baird, George, 22, Lovaine Place, North Shields ... ... (E) Oct. 1892
Baird, Robert, 13, Hylton Terrace, North Shields ... ... (E) Jan. 1890
Barclay, James, Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-on-Tyne ... ...(SUR) Nov. 1888
Barley, C. J., c/o Messrs. The Kensington and Knightsbridge Electric Lighting Co., Chapel Place, Brompton Road, London, S.W. ... ... (E) } Graduate, Feb. 1885; Member, Dec. 1886
Barnett, James Rennie, Lilybank House, Johnston, N.B. ... ... (S) Oct. 1889
Barnsley, John, Field House West, North Shields ... ... (E) May 1892
Barron, T. G., Fern Villas, Elwick Road, West Hartlepool ... (E) Oct. 1888
Barrow, A. R., N.W. Indian Railways, Sukkur, India ... ... (E) Feb. 1891
Bastow, W. W., 112, Scarborough Street, West Hartlepool ... (S) Dec. 1889
Batey, John Thomas, 25, Harrison Place, Newcastle-on-Tyne ... (S) Nov. 1885
Batliboi, Jehangir Framji, 11, Apollo Street, Fort, Bombay ... (E) Dec. 1888
Baxter, J., 26, Simonside Terrace, Heaton, Newcastle-on-Tyne ... (E) Nov. 1884
Beadon, D. C., 68, Park Road, Newcastle-on-Tyne... ... ... (E) Jan. 1885
Bell, Robert Turner, 22, Edith Street, Jarrow-on-Tyne ... ... (S) Oct. 1891
Bell, William, West Wing, Point Pleasant, Wallsend-on-Tyne ... (E) Nov. 1888
Bell, William, Camperdown Shipyard, Dundee, N.B. ... ... (S) April 1893
Bergström, Gus., Bergsund, Stockholm ... ... (N A) Mar. 1886
Berkley, A. B., Grange Villa, Jarrow-on-Tyne ... ... (E) Mar. 1887
Bindesböll, S. C. W., Helsingors Lernskibs Cygerric, Denmark ... (S) Nov. 1884
Black, J., c/o Messrs. J. Merryweather & Co., West Hartlepool ... (E) Nov. 1888
Black, Wm., Messrs. Black, Hawthorn, & Co., Gateshead-on-Tyne (E) Jan. 1885
Blackett, Walter, 60, Marine Parade, Sheerness ... ... (E) Nov. 1892
Blackie, Thomas Reid, Lloyd's Register of Shipping, Dock Office, West Hartlepool ... ... (SUR) Nov. 1890
Blechynden, Alfred, 12, Cavendish Park, Barrow-in-Furness ... (E) Oct. 1885
Blenkinsop, John N., 38, Ashbornham Grove, Greenwich, S.E. ... (E) Oct. 1885

ELECTED.

Blumer, Wm. Riversley, Millum Terrace, Monkwearmouth, Sunderland ... ... (S) Dec. 1886
Boddy, John, 96, Dock Street, Newport, Monmouthshire ... ... (E) Dec. 1888
Bodin, Lauritz M., 27, Argyle Square, Sunderland ... (E & SUR) Dec. 1889
Bond, C. P. W., 27, Leadenhall Street, London, E.C. ... ... (E) Nov. 1888
Bone, W. J., 61, Linskill Terrace, North Shields ... ... (S) Dec. 1884
Bonnyman, James Smith, 13, Ryder Street, Canton, Cardiff ... (E) Nov. 1889
Boolds, Jas. H., c/o Messrs. Raylton Dixon & Co., Cleveland Shipyard, Middlesborough ... ... (S) Oct. 1886
Booth, Edward Spence, c/o C. Furness, Esq., 85, Water Street, Boston, U.S. America ... ... (E) Oct. 1889
Booth, John William, Union Foundry, Rodley, near Leeds ... (E) April 1892
Borowski, G., 15 Line, 8 Hause, 10 Lodge, Ostroff Vassiliefsky, Petersburg, Russia... ... ... (E) Oct. 1885
Boyd, Wm., North House, Long Benton, Newcastle-on-Tyne ... (E) Nov. 1884
Bramwell, Balfour, c/o Messrs. Harland & Wolff, Engine Works, Belfast ... ... (E) { Graduate, Nov. 1886; Member, Nov. 1887 }
Brankston, R. T., 36, Hawthorn Street, Newcastle-on-Tyne ... (E) Nov. 1884
Brown, Eugene, c/o Messrs. J. H. Holmes & Co., Portland Road, Newcastle-on-Tyne ... ... (E E) Feb. 1886
Brown, E. D., Tees Conservancy Commissioners, Graving Dock, N. Ormesby, Middlesborough ... ... (E) Nov. 1888
Brown, James, c/o Sociedad Anonima, de los Astilleros del Nervion, Bilbao, Spain ... ... (E) Mar. 1891
Brown, Robson, Belle Vue Terrace, Tyne Dock ... ... (E) Nov. 1889
Brown, T. R., 110, Roker Avenue, Sunderland ... (E) { Graduate, May 1885; Member, Oct. 1886 }
Brown, William, c/o Messrs. Siemens Brothers & Co., Woolwich ... (E) April 1887
Browne, Sir B. C., Westacres, Benwell, near Newcastle-on-Tyne (C E) Jan. 1885
Bruce, William, c/o Messrs. Harland & Wolff, Belfast ... ... (S) Mar. 1893
Bryson, John Joshua, 4, Hartington Street, Barrow-in-Furness ... (E) Dec. 1892
Buchanan, A., Michaelson Villa, Barrow-in-Furness ... ... (S) Nov. 1884
Buchanan, John H., Oswald Chambers, 5, Oswald Street, Glasgow (SUR) Oct. 1888
Buckland, H. B., Baltic Chambers, Quayside, Newcastle-on-Tyne (E) Nov. 1885
Bull, John Carl, 18, Bexley Road, Erith, Kent ... ... (E) Oct. 1892
Bulmer, John, 1, Graingerville North, Newcastle-on-Tyne ... (E) Mar. 1886
Burdon, J. G., Endfield, Newcastle-on-Tyne... ... ... (E) Nov. 1884
Burnett, Norman, Watergate Buildings, Newcastle-on-Tyne ... (E) Oct. 1891
Butterfield, George, 30, John Candlish Road, Millfield, Sunderland Nov. 1884

C.

Cama, Nusserwanji Bomanji, Sleaton Road, Tardeo, Bombay, British India ... ... (E) Dec. 1888
Cameron, Angus, c/o James Laing, Esq., Deptford Yard, Sunderland (S) Nov. 1892
Cameron, David, 11, Graham Place, Dundee ... ... (E) April 1891
Cameron, Henry, Hazlebank, Trinity, Edinburgh ... ... (E) Oct. 1892
Campbell, J. Jennings, 61, Gloucester Street, Newcastle-on-Tyne... (E) Oct. 1888
Cannell, Frank, Messrs. H. Parry & Son, Lisbon ... ... (E & S) Nov. 1887
Cargey, D. J., Somerville House, Forest Hall, Northumberland ... (E) Nov. 1891
Carstons, Samuel, Messrs. Burmeister & Wains, Maskin-og Skibsbyggeri, Copenhagen, Denmark ... ... (S) Dec. 1887

ELECTED.

Carter, G. J., Elswick Shipyard, Newcastle-on-Tyne ... ... (S) Dec. 1886
Carter, Thos., 49, North Bridge Street, Monkwearmouth, Sunderland (E) Nov. 1884
Casey, James, 10, Philpot Lane, London, E.C. ... ... (E) Nov. 1891
Cay, Arthur, Westoe, South Shields ... ... (E) Nov. 1884
Ceuvel, John L., Kantoor, Gebouw, Amsterdam ... ... (E) Mar. 1886
Chandler, Noel, Messrs. Bumsted & Chandler, Cannock Chase Engine Works, Hednesford, Staffordshire ... ... (E) Oct. 1891
Chapman, Abel, Capt., Belle Vue, Low Fell, Gateshead-on-Tyne... (E) Nov. 1884
Chapman, Harry Reynolds, Messrs. Clarke, Chapman, & Co., Gateshead-on-Tyne ... ... (E) Mar. 1893
Chapman, Hedley, 147, Park Road, Newcastle-on-Tyne ... ... (E) Feb. 1886
Charlton, Henry, 1, Millfield Terrace, Gateshead-on-Tyne... ... (E) Nov. 1884
Charlton, R. B., Jun., Manors Railway Station Works, Newcastle-on-Tyne ... ... (E) Nov. 1884
Charlton, T., 25, Lincoln Street, Gateshead-on-Tyne ... ... (E) Nov. 1884
Charlton, Thomas, The Cedars, Millhill, West Cowes, Isle of Wight (E) Nov. 1890
Chicken, Thomas, c/o Messrs. Newport Engineering and Ship Repairing Co., Newport, Monmouth ... ... (E) Oct. 1892
Chisholm, Alexander, 2, Kent Villas, Kent Street, Jarrow-on-Tyne (S) Mar. 1893
Christie, C. A., 4, Woodside, Tynemouth ... ... (E) Nov. 1884
Christie, C. J. D., Neptune Works, Walker-on-Tyne ... ... (S) Nov. 1884
Christie, J. D., 4, Colbeck Terrace, Tynemouth ... ... (S) Nov. 1884
Churchill, James Dixon, 9, London Street, London, E.C. ... ... (E) Oct. 1889
Clark, Geo., Southwick Engine Works, Sunderland ... ... (E) Nov. 1884
Clark, George, Jun., Southwick Engine Works, Sunderland ... (E) Feb. 1888
Clark, Henry, Southwick Engine Works, Sunderland ... ... (E) Oct. 1887
Clark, James Carver, 5, Rium Terrace, West Hartlepool ... ... (E) Nov. 1892
Clarke, Henry Trevisa, c/o James Laing, Esq., Deptford Shipyard, Sunderland ... ... (S) Mar. 1892
Clarke, Thos., 82, Rye Hill, Newcastle-on-Tyne ... ... (E) Nov. 1884
Conning, Alfred C., Dunston Iron & Steel Works, Gateshead-on-Tyne (F M) May 1885
Conràdi, Carl, 8, Toldbodgaden, Christiana, Norway ... ... (E) Nov. 1884
Consiglio, Luigi, 8, Via Paterno, Palermo ... ... (N A) Nov. 1890
Cooper, Nusserwanji Naoroji, Indo-China Mills, Sewree, Bombay, India ... ... (E) Oct. 1889
Cooper, William, Baltic Chambers, Quayside, Newcastle-on-Tyne (E) Feb. 1888
Coote, Arthur, Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne ... ... (S) Nov. 1884
Copeman, William C. J., 10, Brinkburn Terrace, South Shields ... (E) Oct. 1892
Cornish, H. P., 396, Glossop Road, Sheffield ... ... (E) Oct. 1888
Couche, Henry Drew, c/o Messrs. Palmer's Shipbuilding and Iron Co., Jarrow-on-Tyne ... ... (E) Oct. 1891
Courtier-Dutton, W. T., British Corporation Registry of Shipping, 69, St. Vincent Street, Glasgow ... ... (S SUR) April 1890
Cowens, William Edward, c/o Messrs. John Abbot & Co., Gateshead-on-Tyne ... ... (E) Dec. 1889
Craggs, Ernest H., Messrs. R. Craggs & Sons, Middlesborough ... (S) Oct. 1888
Craig, John C., Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-on-Tyne ... ... (E SUR) Oct. 1890
Craig, Robert, 13, Milton Street, West Hartlepool ... ... (E) Nov. 1892
Crawford, Jas., 9, Custom House Court, Quayside, Newcastle-on-Tyne ... ... (S SUR) Nov. 1886

ELECTED.

Crawford, W. A. F., Westminster Chambers, 9, Victoria Street, London, S.W. ... ... (E) Nov. 1884
Cross, Wm., 24, Windsor Terrace, Newcastle-on-Tyne ... ... (E) Mar. 1886
Cruddas, W. D., Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick, Newcastle-on-Tyne ... ... (E) Dec. 1884
Cruickshank, Alexander, Engineer's Office, Cumberland Basin, Bristol Docks, Bristol ... ...(SUR) Mar. 1892
Cumming, Alexander, 20, Lorne Terrace, Sunderland ... ... (E) Nov. 1891
Cummins, W. R., 6, Roseangle, Dundee ... ... (E) Nov. 1884
Curwen, Henry R., 4, Victoria Road, Tranmere Park, Birkenhead ... ... (S) { Graduate, Feb. 1886; Member, Oct. 1887 }

D.

Dadd, Edward Martin, c/o Messrs. The Oriental Steamship Co., 84, Leadenhall Street, London, E.C. ... ... (E) Mar. 1892
Dalrymple, Wm., 14, Brinkburn Terrace, South Shields ... ... (E) Dec. 1886
Darling, W. J., Lloyd's Register of Shipping, Dock Chambers, Barry ... ... (S) April 1887
Darney, John, c/o Messrs. Short Bros., Pallion, Sunderland ... (S) Nov. 1884
Davie, Albert, c/o Messrs. W. Denny & Bros., Leven Shipyard, Dumbarton, N.B. ... ... (E) { Graduate, Feb. 1886; Member, Oct. 1887 }
Davison, A. J., Rosedale, Wallwood Road, Leytonstone, Essex ... (E) Oct. 1888
Denny, Archibald, c/o Messrs. W. Denny & Bros., Dumbarton ... (S) Dec. 1891
De Rusett, Edwin W., Warden House, Percy Park Road, Tynemouth ... ... (S) Nov. 1890
Dick, Francis, 6, Gladstone Street, Sunderland ... ... (E) Nov. 1885
Dick, F. W., c/o Messrs. Palmer's Shipbuilding Co., Jarrow-on-Tyne ... ... (I. & S. M.) Oct. 1891
Dickinson, F. T., 23, Park Place W., Sunderland ... (E) { Graduate, May 1885; Member, Oct. 1886 }
Dickinson, James, The Cloisters, Sunderland ... ... (E) Nov. 1884
Dickinson, John, Park House, Sunderland ... ... (E) Nov. 1884
Dickinson, R. E., c/o Messrs. The Bowling Iron Co., Bradford, Yorkshire ... ... (E) April 1889
Dickinson, W., Park House, Sunderland ... ... (E) Nov. 1884
Dixon-Brown, L. D., Unthank Hall, Haltwhistle ... ... (S) Nov. 1886
Dixon, John Rochester, 79, Osborne Road, Newcastle-on-Tyne ... (E) Feb. 1893
Dixon, Sir Raylton, Cleveland Shipyard, Middlesborough ... (S) Feb. 1888
Dobson, William, Shipbuilder, Walker-on-Tyne ... ... (S) Nov. 1888
Donald, George Gray, 2, South Preston, North Shields ... ... (E) Oct. 1890
Donald, James, 48, St. Luke's Terrace, Pallion, Sunderland ... (S) Nov. 1884
Donkin, George, St. Andrew's Engine Works, Newcastle-on-Tyne (E) Oct. 1892
Donovan, J. W., 5, Ash Place, Newcastle Road, Sunderland ... (E) April 1885
Douglas, John F., c/o Messrs. Ramage & Ferguson, Leith ... ... (E) Jan. 1888
Dowsen, Chas., 21, Croft Terrace, Jarrow-on-Tyne ... ... (E) Dec. 1885
Doxford, Charles D., Bainbridge Holme, Tunstall Road, Sunderland (S) Nov. 1884
Doxford, R. P., Pallion Engine Works, Sunderland ... ... (E) Nov. 1884
Doxford, W. Theodore, Pallion Shipyard, Sunderland ... ... (S) Nov. 1884
Drake, William Edward, 7, Rodwell Terrace, Weymouth ... ... (E) Feb. 1893
Drakenberg, J. A., 73, Nybrogatan, Stockholm, Sweden ... ... (E) Feb. 1886
Duckitt, Jno., 4, St. Nicholas' Buildings West, Newcastle-on-Tyne (E) Nov. 1884

ELECTED.

Dudgeon, F. S., 112, Fenchurch Street, London, E.C. ... ... (E) Feb. 1885
Duguid, Robert, 108, Byker Street, Walker-on-Tyne ... ... (S) Oct. 1892
Dunlop, William, 31, Hartington Street, Barrow-in-Furness ... (E) Mar. 1888
Dyer, Charles M. B., c/o Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-on-Tyne ... ... (E SUR) Oct. 1892
Dykes, George, 34, Lloyd Strasse, Bremerhaven ... ... (S) Jan. 1893
Dykes, James, 27, Belgrave Terrace, Newcastle-on-Tyne ... ... (E) May 1885
Dykes, John, Lloyd's Register of Shipping, Oriel Chambers, Liverpool ... ...(SUR) Oct. 1889

E.

Eckmann, John ... ... (E) May 1885
Edgar, George, Clythie Crescent, Newport, Monmouthshire ... (E) Oct. 1891
Edmiston, Jas. B., Ivy Cottage, Highfield Road, Walton, Liverpool (E) Nov. 1886
Edwards, James Harry, 15, The Lawe, South Shields ... ... (S) Mar. 1893
Eeles, Robert, Queen Street, Newcastle-on-Tyne ... ... (E) April 1889
Elliot, Henry, c/o Sociedad Anonima, Astilleros del Nervion, Bilbao, Spain... ... ... (E) May 1891
Ellis, Robert Elwood, Messrs. Cumming & Ellis, Inverkeithing, Fife ... ... (S) Feb. 1891
Eltringham, Joseph T., Stone Quay, South Shields ... ... (S & B B) Oct. 1889
English, Thos. (Lieut.-Col.), Messrs. Palmer's Shipbuilding & Iron Co., Jarrow-on-Tyne ... ... (E) Oct. 1890
Eshelby, William, 1, Lax Terrace, Stockton-on-Tees ... ... (E) Feb. 1888
Evans, Charles, c/o Messrs. Hawthorn, Leslie, & Co., Engine Works, St. Peter's, Newcastle-on-Tyne ... ... (E) Mar. 1891
Evans, Lewis, c/o Ralph Carr, Esq., Maritime Buildings, King Street, Newcastle-on-Tyne ... ...(SUR) Dec. 1890
Evans, William, Superintendent Engineer, Caerphilly, near Cardiff (E) Nov. 1889
Evers, G., Lubeck, Germany ... ... (S) Nov. 1884

F.

Fairman, A. E. ... ... (N A) Oct. 1886
Farina, A. J., 63, Quayside, Newcastle-on-Tyne ... ... (E) Nov. 1884
Faruffini, Capt. M. C., c/o Connitato Pei Designa delle Navi Ministero dilla Marina, Rome, Italy .... (N A) Dec. 1888
Feldtmann, H., Surveyor to Bureau Veritas, Bergen, Norway ... (E) Jan. 1889
Fenwick, James, B.Sc., C.E., Belmore House, Belmore, near Sydney, New South Wales ... ... (E) Oct. 1892
Ferrier, Robert M., B.Sc., Durham College of Science, Barras Bridge, Newcastle-on-Tyne ... ... (E) Nov. 1892
Filley, George Frederick, 25, Caroline Street, Jarrow-on-Tyne ... (S) Nov. 1891
Findlay, John Taylor, 14, Nelson Street, Sunderland ... ... (S) Feb. 1890
Fish, Thomas Wilson, Lloyd's Register of Shipping, Glasgow ...(SUR) May 1892
Fleming, Charles Edward, 71, Elswick Road, Newcastle-on-Tyne (E) Nov. 1884
Fletcher, James, 11, Ibrox Place, Whitefield Road, Ibrox, Glasgow (E) Dec. 1885
Fletcher, Robert, Walker Forge, Walker-on-Tyne ... ...(F M) Dec. 1886
Flohr, Justus, Elisabethstrasse 10, Stettin, Germany ... ... (E) Oct. 1886
Foley, Nelson, Villa Beatrice, Parco Griffeo, Naples, Italy ... (E) Nov. 1884
Ford, David, c/o Sociedad Anonima, Astilleros del Nervion, Bilbao, Spain ... ... (E) May 1891

ELECTED.

Forster, William, c/o Messrs. Dixon, Robson, & Co., 2, Collingwood Street, Newcastle-on-Tyne ... ... (E) Mar. 1890
Foster, Henry, Newburn Steel Works, Newburn-on-Tyne ... ... (E) April 1885
Fothergill, J. R., 1, Bathgate Terrace, West Hartlepool ... ... (E) Mar. 1886
Fowell, Ridley, Lloyd's Register of Shipping, Dock Offices, West Hartlepool ... ... (E) Feb. 1893
Fowling, Charles, Lloyd's Register of Shipping, Dock Office Buildings, West Hartlepool ... ... (S) Nov. 1892
Fownes, Henry, Tyne Forge, Ouseburn, Newcastle-on-Tyne ... (F M) Nov. 1884
Fox, Samson, Messrs. The Leeds Forge Co., Leeds (*Life Member*) (E) Dec. 1887
Franki, J. P., c/o Messrs. Morts Dry Dock and Engineering Co., Sydney, N.S.W., Australia ... ... (E) Jan. 1886
Fraser, John Imbrie, c/o Messrs. Harland & Wolff, Engine Department, Belfast ... ... (E) Oct. 1891
Furneaux, J. B., Victoria Engine Works, Gateshead-on-Tyne ... (E) Nov. 1885
Furness, John ... ... (E) Nov. 1885
Furse, Fred., Villa Schlaepfer, Capodimonte, Naples ... ... (S) April 1887

G.

Gannaway, H. G., 11, Kent Street, Jarrow-on-Tyne ... ... (S) Nov. 1884
Garratt, H. A., University College, Bristol ... ... (E) { Graduate, Nov. 1884 / Member, Nov. 1886
Garthwaite, John R., c/o Messrs. R. Ropner & Sons, Stockton-on-Tees (S) May 1889
Gayner, Robt. H., Jun., Beech Holm, Sunderland ... (E) { Graduate, Mar. 1886 / Member, Oct. 1888
Gearing, Ernest George, 76, Cardigan Road, Headingley, Leeds ... (E) Dec. 1892
Geddes, Christopher, 23, Brunswick Street, Liverpool ... ... (E) Oct. 1888
Gemmell, James C. R., Pier No. 55, North River, New York, U.S.A. (E) Feb. 1892
Gibson, H., 162, Roker Avenue, Monkwearmouth, Sunderland ... (S) Nov. 1884
Gibson, John W., 1, Bellerby Terrace, West Hartlepool ... ... (B B) Nov. 1891
Gibson, W. H., 37, Tatham Street, Sunderland ... ... (E) Nov. 1884
Glover, Terrot, 6, Azalea Terrace, Sunderland ... ... (E) Mar. 1886
Goddard, George Arthur, 5, Rose Street, Gosforth, Newcastle-on-Tyne ... ... (E) Feb. 1890
Gordon, William James, c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness ... ... (E) Oct. 1887
Gordon, William Leslie, Invermark Terrace, Barnhill, Broughty Ferry, N.B.... ... ... (E) April 1893
Graham, Edwin, Messrs. Osbourne, Graham, & Co., Hylton, Sunderland ... ... (S) Nov. 1884
Graham, Wm., Ford Lodge, South Hylton, near Sunderland ... (S) Nov. 1884
Graham, William, 35, Hawthorn Street, Newcastle-on-Tyne ... (S) Oct. 1891
Graham, William, Los Astilleros del Nervion, Bilbao, Spain ... (S) April 1893
Gravell, John, Custom House Court, Quayside, Newcastle-on-Tyne (N A SUR) Nov. 1884
Gray, A., 17, Belgrave Terrace, Newcastle-on-Tyne... ... ... (E) Nov. 1888
Gray, George, 13, Harold Street, Sunderland ... ... (E) Feb. 1888
Gray, Harry, 12, Grosvenor Road, Jesmond, Newcastle-on-Tyne ... (E) Dec. 1885
Gray, Matthew, Messrs. W. Gray & Co., West Hartlepool... ... (S) Oct. 1888
Gray, Sir William, Messrs. W. Gray & Co., West Hartlepool (S & E) Oct. 1888

ELECTED.

Green, W. G., c/o Messrs. Palmer's Iron and Shipbuilding Co., Jarrow-on-Tyne ... ... (E) Nov. 1884
Green, William, c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness ... ... (E) Oct. 1885
Greig, David William, 31, Westmorland Road, Newcastle-on-Tyne (E) Mar. 1891
Grieves, Robert, 38, Linskill Terrace, North Shields (S) { Graduate, Nov. 1884 / Member, Dec. 1886
Grimes, Thomas Benjamin, 45, Eastbourne Grove, South Shields... (E) Mar. 1890
Gross, Felix, Assistant Manager, c/o Messrs. John Brown & Co., Atlas Works, Sheffield ... ... (I & S M) Feb. 1893
Guest, Thomas, 4, Coxon Street, Sunderland ... ... (S) April 1893
Gulston, A., Clayton Park Lodge, Jesmond, Newcastle-on-Tyne ... (E) Dec. 1888

H.

Hake, G. A., 29, Rothbury Terrace, Heaton, Newcastle-on-Tyne ...(SUR) Oct. 1888
Hall, Edward, c/o Sociedad Anonima, Astilleros del Nervion, Bilbao, Spain ... ... (S) Nov. 1885
Hall, J. Percy, Carville, Laurie Park Road, Sydenham, London, S.E. (E) Oct. 1885
Hall, John W., Abden Shipyard, Kinghorn, N.B. ... ... (S) Oct. 1887
Hall-Brown, E., c/o Messrs. Hall-Brown, Buttery, & Co., Helen Street Engine Works, Govan, Glasgow... ... ... (E) Nov. 1888
Halley, David, Messrs. Burmeister & Wains, Maskin-og Skibsbyggeri, Copenhagen, Denmark (*Life Member*) ... ... (E) Feb. 1887
Hamilton, John, c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness ... ... (E) Nov. 1886
Hamilton, J. H., B.Sc., Engine Works, Sandiacre, near Nottingham (E) Nov. 1888
Hamilton, R. R., c/o Messrs. Maudslay, Sons, & Field, Lambeth, London ... ... (E) Nov. 1884
Hammar, Hugo G., Bureau of Construction and Repairs, U.S. Navy Yard, Brooklyn, New York, U.S.A. ... ... (S) Nov. 1890
Hansen, F. T., Moss Jernstöberi og Mek Værksted, near Christiania, Norway ... ... (E) Nov. 1884
Harding, J. C., 4, Queen's Road, Erith, Kent ... ... (E) Nov. 1884
Hardy, Arthur Francis, 13, Regent Street, London, S.W. ... ... (S) Oct. 1887
Harkness, Richard, 8, Grenville Terrace, Grange Road, West Hartlepool ... ... (S SUR) Nov. 1884
Harlow, F., 15, Clayton Park Square, Newcastle-on-Tyne... ... (E) Nov. 1884
Harman, Bruce, c/o Messrs. A. & W. Smith & Co., Eglington Engine Works, Glasgow .. .. (E) Oct. 1886
Harper, J. H., 1, Beaumont Street, North Shields ... ... (E) Jan. 1885
Harris, Anthony, c/o Messrs. Copley, Taylor, & Co., Engineers, Middlesborough ... ... (E) Mar. 1892
Harrison, Alfred, Scotia Engine Works, Sunderland ... ... (E) Oct. 1889
Harrold, Alexander, 26, Brunel Terrace, Newcastle-on-Tyne ... (E) Nov. 1884
Harrold, F., 14, Rowell Street, Hartlepool ... ... (E) Nov. 1888
Hartness, J., East Boldon, near Sunderland ... ... (E) Nov. 1884
Harvey, John W. J., 1, Richmond Villa, Chertsey Road, Bristol ... (E) Feb. 1889
Haswell, Robert ... ... (S) Dec. 1888
Havelock, Michael, 6, Exchange Buildings, King Street, Newcastle-on-Tyne ... ... (E) Dec. 1887
Head, Archibald P., Queen's Square, Middlesborough-on-Tees ... ... (E) { Graduate, Nov. 1884 / Member, Oct. 1887

ELECTED.

Headlam, Robert, 5, Edward Street, Stockton-on-Tees ... ... (E) Nov. 1886
Heck, John H., Lloyd's Register of Shipping, Newport, Monmouthshire ... ... (S SUR) Nov. 1885
Henderson, Alex., c/o Messrs. Empreza, Nacional, De. Nav. D'Vapor (E) April 1893
Henderson, A. M., 3, Greatham Terrace, West Hartlepool ... (E) Nov. 1890
Henderson, George, 54, Westmorland Road, Newcastle-on-Tyne ... (E) Nov. 1884
Henderson, Robert, 30, Lovaine Crescent, Newcastle-on-Tyne ... (S) Nov. 1884
Hepburn, Alfred, Northumberland Forge, Wallsend-on-Tyne ... (F M) Dec. 1890
Hepple, William, Slipway, North Shields ... ... (E & S) Oct. 1885
Hildrey, A. J., 11, Chester Street, Sunderland ... ... (S) Nov. 1884
Hill, Alfred William, Otterburn Terrace, Newcastle-on-Tyne ... (I M) Oct. 1891
Hill, Maxwell, 1, St. Nicholas' Buildings, Newcastle-on-Tyne ... (S) Nov. 1884
Hills, Charles Henry, Anglesey Copper Works, Walker-on-Tyne ... (E) Nov. 1889
Hindson, William, Bensham Lodge, Gateshead-on-Tyne ... ... (E) Nov. 1884
Hindson, William Forster, 7, Elysium Lane, Bensham, Gateshead-on-Tyne ... ... (E) Nov. 1892
Hines, William, H.M.S. "Karrakatta," Royal Navy, Sydney, Australia (E) Mar. 1890
Hirst, Richard, 4, Cleveland Road, North Shields ... ... (E SUR) Nov. 1885
Hodge, Rowland F. W., Messrs. C. S. Swan & Hunter, Wallsend-on-Tyne ... ... (S) Dec. 1890
Hogg, James, 8, Lovaine Terrace, North Shields ... ... (B F) Nov. 1889
Hök, Wilhelm, Deptford Shipyard, Sunderland ... ... (S) Oct. 1886
Hollis, Henry William, Whitworth House, Spennymoor ... ... (I M) Oct. 1891
Holmes, John H., Portland Road, Newcastle-on-Tyne ... ... (E) Jan. 1888
Homji, A. C. N., 13, Trinity Street, Dhobie, Talao, Bombay, India (E) Nov. 1884
Hooper, Ernest, 23, Whitehall Terrace, Sunderland ... ... (E) Nov. 1885
Hopkinson, Frank A., c/o Messrs. J. Hopkinson & Co., Huddersfield (E) Dec. 1891
Hunter, George B., Messrs. C. S. Swan, Hunter, & Co., Wallsend-on-Tyne ... ... (S) Nov. 1884
Hunter, J. W., Pendleton House, Stockton Road, Sunderland ... (E) May 1885
Hunter, Summers, c/o Messrs. N.E. Marine Engineering Co., Northumberland Engine Works, Wallsend-on-Tyne ... ... (E) Nov. 1885
Hutchinson, C. W., 6, Park Parade, Westmorland Road, Newcastle-on-Tyne ... ... (E) Nov. 1884
Hutchinson, Wesley, B.A., 6, Park Parade, Newcastle-on-Tyne ... (E) Oct. 1891
Hutchison, J., Board of Trade Offices, West Hartlepool ... ...(SUR) Dec. 1891
Hutchison, Thomas Allan, 22, Wharncliffe Street, Newcastle-on-Tyne ... ... (S) Nov. 1891

I.

Inglis, John, c/o Messrs. Hawthorn & Co., Leith ... ... (S) April 1887
Inglis, John, Jun., Pointhouse Shipyard, Partick, Glasgow ... (E) Oct. 1886
Inman, Douglas S., 17, Wandsworth Road, Heaton, Newcastle-on-Tyne ... ... (E) Oct. 1892
Irwin, J. H., Sunderland Engine Works, South Docks, Sunderland (E) Nov. 1884
Irwin, Thomas F., 1, St. Alban's Road, Bootle, near Liverpool ... ...(C E & N A) Mar. 1888

J.

Jackson, A., Surveyor's Office, Board of Trade, North Shields (E SUR) Nov. 1888
Jackson, Herbert Stonewall, c/o Messrs. Westgarth, English, & Co., Middlesborough ... ... (E) Dec. 1891

ELECTED.

Jackson, Vincent, 5, Beaconsfield Street, Hartlepool ... ... (S) April 1888
Jackson, William S., Messrs. Gourlay Bros. & Co., Camperdown Shipyard, Dundee ... ... (S) April 1891
James, M. C., 79, West Street, Gateshead-on-Tyne ... ... (S) Nov. 1884
Jamieson, John, 25, Azalea Terrace South, Sunderland ... ... (E) Nov. 1885
Jeffrey, Philip, 98, Park Road, Newcastle-on-Tyne ... ... (E) Dec. 1892
Jobling, J. C., Blackwall Ironworks, Isle of Dogs, London, E. ... (E) Nov. 1884
Jobling, W. J., 1, Akenside Hill, Newcastle-on-Tyne ... (E & S O) Nov. 1884
John, Edmund, Barry Dock, Cardiff ... ... (E) Dec. 1889
Johnson, Alexander, 12, Wandsworth Road, Heaton, Newcastle-on-Tyne ... ... (E) Feb. 1892
Johnson, Johan, 7, Vestra Hamngaten, Gothenburg, Sweden ... (S) May 1885
Johnson, T. Allan, 15, Stannington Avenue, Heaton, Newcastle-on-Tyne ... ... (S) Nov. 1884
Johnstone, William, Lloyd's Register of Shipping, Barrow-in-Furness ... ...(SUR) Nov. 1884
Joicey, Jacob G., Forth Banks West Factory. Newcastle-on-Tyne (E) Jan. 1889
Jones, George, c/o Messrs. W. Gray & Co., West Hartlepool ... (S) Oct. 1888
Jones, Morlais G., 6, Delahay Street, Westminster, London, S.W....
Jorgenson, F., Inspector to Austrian Lloyd's, Constantinople ...(SUR) Nov. 1888

K.

Keene, H. R., Lloyd's Register of Shipping, Exchange Buildings, Middlesborough ... ... (E) { Graduate, May 1885 / Member, April 1887
Kendall, Stonard O., c/o J. Gravell, Esq., Bureau Veritas, Custom House Court, Quayside, Newcastle-on-Tyne ... ... (SUR) Mar. 1891
Kerfoot, James, 7, Queen's Terrace, Jesmond, Newcastle-on-Tyne (E) Oct. 1892
Kilvington, W., 25, Claremont Place, Newcastle-on-Tyne ... ... (E) Nov. 1884
King, Donald, Engineering Department, Sociedad Anonima, Astilleros del Nervion, Bilbao, Spain ... ... (E) Jan. 1890
Kirkaldy, John, 40, West India Dock Road, London ... ... (E) Nov. 1885
Kitching, J. F., c/o Messrs. Simpson, Spence, & Young, Scandinavian Chambers, West Hartlepool ... ... (E) Nov. 1890
Knaffl, Alvis, c/o Norddeutscher Lloyd, Bremerhaven ... ... (E) Mar. 1893
Kodolitsch, Felix de, Arsenale del Lloyd Austriaco, Trieste ... (E) Nov. 1892

L.

Laidley, R. W., 10, Hunter Street, Sydney, N.S.W., Australia ... (E) April 1887
Laing, Andrew, Fairfield Works, Govan, Glasgow ... ... (E) Oct. 1892
Laing, Arthur, Deptford Shipyard, Sunderland ... ... (S) Nov. 1884
Laing, Jas., Jun., Deptford Yard, Sunderland ... ... (S) Nov. 1884
Laing, John, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Nov. 1884
Larkin, James, 2, William Black Street, East Jarrow-on-Tyne ... (E) Nov. 1884
Laurie, Leonard George, Newport, Monmouthshire ... ... (E) Oct. 1891
Lewis, R. A., Newburn Steel Works, Newburn-on-Tyne ... ... (E) Nov. 1884
Liddell, J., c/o Messrs. Denny & Co., Engine Works, Dumbarton... (E) Nov. 1884
Lindfors, Hugo, 16, Alexandersgatan, Helsingfors, Finland ... (S) May 1889
Lineham, Wilfrid J., Goldsmiths' Co., Technical Institute, New Cross, London, S.E. ... ... (E) Oct. 1890
List, John, Orchard House Works, Blackwall, London, E. ... (E) April 1891

		ELECTED.
Littleboy, Chas. Wm., 2, Lorne Terrace, Stockton-on-Tees ...	(S)	Oct. 1887
Livingston, Thos., Dunedin House, Jarrow-on-Tyne	(S)	Nov. 1884
Livingstone, John, 6, Simonside Terrace, Heaton, Newcastle-on-Tyne	(E)	Nov. 1884
Lohmeyer, H., 43, Crown Street, Newcastle-on-Tyne	(E)	Nov. 1884
Long, A. E., 124, Albert Road, Jarrow-on-Tyne	(S)	Nov. 1884
Lowdon, John, Messrs. Barry Graving Dock and Engineering Co., Limited, Barry Dock, near Cardiff	(E)	Dec. 1891

M.

MacColl, Hector, Messrs MacIlwaine & MacColl, Belfast	(E)	Dec. 1890
Maccoy, John, 55, Larkspur Terrace, Newcastle-on-Tyne	(E)	Feb. 1886
MacDonald, David R., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick Shipyard, Newcastle-on-Tyne	(S)	Nov. 1891
Mace, W., 253, Albert Road, Jarrow-on-Tyne	(E)	Jan. 1886
Macfarlane, Andrew, 18, John Street, Sunderland	(E)	Dec. 1890
MacGregor, John, 2, Michaelston Villas, Barrow-in-Furness ...	(E)	Mar. 1888
MacHaffie, John, 635, Terrace Place, Schenectady, New York, U.S.A.	(E)	Dec. 1885
Mackay, William, 18, Ainslie Street, Barrow-in-Furness	(S)	Mar. 1892
Macmillan, Walter, c/o Sociedad Anonima, Astilleros del Nervion, Bilbao, Spain	(E)	May 1891
Macoll, D. C., 6, Gosforth Street, Monkwearmouth, Sunderland...	(S)	Nov. 1884
Macoll, Hugh, 4, Azalea Terrace North, Sunderland (*Life Member*)	(S)	Nov. 1884
Marlborough, Richard, 11, Brookland Road, Sunderland	(S)	Nov. 1884
Marr, James, 6, Ash Place, Sunderland	(S)	Nov. 1884
Marshall, F. C., 38, Percy Gardens, Tynemouth	(E)	Nov. 1884
Marshall, Frank T., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne	(E)	Graduate, Jan. 1885 Member, Oct. 1888
Marshall, R. J., 51, Larkspur Terrace, Jesmond, Newcastle-on-Tyne	(E)	Mar. 1887
Martell, Charles	(E)	Nov. 1891
Mastaglio, W. D., 65, Warrington Road, Newcastle-on-Tyne ...	(E)	Nov. 1885
Mather, Charles, 44, Warrington Road, Newcastle-on-Tyne ...	(SUR)	Oct. 1888
Matheson, William, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne	(S)	Dec. 1889
Matthews, A., The Baths, Blyth	(S)	Nov. 1884
Matthews, Jas., c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Forth Banks, Newcastle-on-Tyne	(E)	Oct. 1886
Mavor, Alfred E., Victoria Mansions, 32, Victoria Street, London, S.W.	(E E)	Feb. 1890
McDougall, Neil, Managing Director British Steam Users' Insurance Society, Ld., 4 & 5, Victoria Buildings, Manchester ...	(E)	Mar. 1890
McGlashan, Arch., 26, Milton Street, West Hartlepool	(S)	Nov. 1885
McIlvenna, J. G., c/o Messrs. The Tyne Pontoon and Dry Docks Co., Wallsend-on-Tyne	(S)	Nov. 1884
McKay, Jno., 19, Victoria Avenue, Whitley-by-the-Sea	(E)	Nov. 1884
Menzies, Wm., The Side, Newcastle-on-Tyne	(E)	Nov. 1884
Messenger, Thomas, 2, Clarence Lawn, Dover, Kent	(E)	Mar. 1887
Metcalf, J. C., 4, Azalea Terrace North, Sunderland ...	(SUR)	Nov. 1884
Metcalfe, C. S., 24, Croft Avenue, Sunderland	(E)	Nov. 1884
Micheli, Pietro, Jun., 20, Via Luccoli I°. P°., Genoa ...	(E & N A)	Oct. 1888
Middlemass, Thomas, 3, Albert Place, Norton Road, Stockton-on-Tees	(S)	Oct. 1889
Middleton, H., Tyne View House, Whickham, Durhamshire	(I & S M)	Jan. 1893

ELECTED.

Middleton, Robert Alexander, Fairfield Works, Govan, Glasgow ... (N A) Oct. 1892
Milburn, Christopher J., 14, Falmouth Road, Heaton, Newcastle-on-Tyne ... ... (E) Feb. 1888
Millar, Thos., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Walker Shipyard, Walker-on-Tyne ... ... (S) Nov. 1884
Miller, Thomas B., 28, Mount Stuart Square, Cardiff (E) {Graduate, Nov. 1886 / Member, Oct. 1888}
Mills, John, c/o Messrs. Greenock Steam Shipping Co., Greenock ... ... (E) Feb. 1888
Mills, William, East Boldon, near Sunderland ... ... (E) Feb. 1890
Milne, W. J., 2, Westbourne Avenue, Walker-on-Tyne ... ... (S) Nov. 1884
Milton, J. T., Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ... (E SUR) Nov. 1886
Mitchell, Chas., Jesmond Towers, Newcastle-on-Tyne ... ... (S) Nov. 1884
Moffitt, George, 42, Stanley Street, Blyth ... ... (S) Oct. 1888
Moffitt, Robert, 13, Grace Terrace, Sunderland ... ... (E) Dec. 1885
Moody, Thomas V., Riding Mill, Northumberland ... ... (E) Dec. 1887
Moore, Frederick, Crighton Chambers, 104, Bute Docks, Cardiff... (E) Oct. 1890
Morgan, W. H., 24, Rochdale Street, Wallsend-on-Tyne ... ... (E) Nov. 1884
Morison, D. B., 8, Albion Terrace, Hartlepool ... ... (E) Feb. 1885
Mörk, Peter, Lennox Hotel, Dumbarton, N.B. ... ... (E) Nov. 1884
Morrison, Robt., 5, Challoner Terrace, South Shields ... ... (E) Nov. 1886
Morrison, William, Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-on-Tyne ... ... (E SUR) Oct. 1890
Morton, Richard Fraser, Lloyd's Register of Shipping, Newcastle-on-Tyne ... ... (E SUR) Oct. 1890
Mountain, William Chas., Messrs. E. Scott & Co., Close, Newcastle-on-Tyne ... ... (E E) Feb. 1889
Mudd, Thomas, Central Marine Engine Works, West Hartlepool (E) Mar. 1886
Muir, Alfred Edward, 21, Joannah Street, Sunderland ... ... (S) Mar. 1893
Muir, John, 10, Rium Terrace, Hart Road, West Hartlepool ... (E) Oct. 1888
Muir, Robert, 17, Westmorland Road, Newcastle-on-Tyne ...(SUR) Oct. 1886
Muir, Robert Home, 24, Lovaine Place, Newcastle-on-Tyne ... (S) Oct. 1892
Myles, David, Northumberland Engine Works, Wallsend-on-Tyne (E) Nov. 1884

N.

Nastoupil, John, Chief Engineer, Austro-Hungarian Navy, Marine Casino, Pola, Austria ... ... (E) Nov. 1890
Newbigin, Henry Thornton, 153, Weardale Street, Mount Pleasant, Spennymoor ... ... (E) Mar. 1892
Newitt, Leonard, c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Elswick Works, Newcastle-on-Tyne ... ... (E E) Dec. 1887
Newton, Richard, Park Square, West Hartlepool ... ... (E) April 1889
Newton, W. A., 29, Sea View Terrace, South Shields (E) {Graduate, May 1885 / Member, Oct. 1886}
Nichol, Thos. ... ... (SUR) Nov. 1884
Nicol, John M., 10, Linskill Place, North Shields ... ... (E) Nov. 1884
Nicolson, G. C., c/o Mr. Shearer, Victoria Jubilee School, Byker, Newcastle-on-Tyne ... ... (E) {Graduate, Oct. 1885 / Member, Oct. 1888}
Nicolson, J. T., McGill University, Montreal, Canada ... ... (E) Nov. 1884
Noble, George, 40, Westgate Road, Newcastle-on-Tyne ... ... (E) May 1893

ELECTED.

Noble, Harry, Northern Machine Tool Works, Forth Road, Newcastle-on-Tyne ... ... (E) Nov. 1888
Noble, J., 48, Marine Approach, South Shields ... ... (E) Oct. 1892
Nodder, Joseph, 503, Pitsmoor Road, Sheffield ... ... (F M) May 1893
Norman, W. S., Orchard House, Whitby, near Chester ... ... (E) Nov. 1884
Norton, Harold P., U.S.S. Concord, Bureau Steam Engineering, Navy Department, Washington, U.S.A. ... ... (E) Oct. 1890
Noton, F. R., 32, Azalea Terrace, Sunderland ... ... (S) Nov. 1884
Nunes, Enrique E., Engineer, Argentine Navy, 433, Calle Ayacucho, Buenos Ayres ... ... (E) April 1891

O.

Oliver, Hedley, 6, Tower Chambers, Water Street, Liverpool ... (E) Oct. 1892
O'Neil, J. J., 2, Erith Terrace, Sunderland ... ... (E) Nov. 1884
Orde, E. L., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Walker Shipyard, Newcastle-on-Tyne ... ... (E) Oct. 1887
Orlando, Chev. Giuseppe, Cantiere Navale, Fratelli Orlando, Leghorn ... ... (N A) Jan. 1893
Oxley, G., 39, Norman Terrace, Howdon-on-Tyne ... ... (S) Nov. 1884

P.

Pacey, John W., c/o Messrs. Midland Coal, Coke, & Iron Co., Apendale, near Newcastle, Staffordshire ... ... (E) Feb. 1888
Parsons, Hon. Charles A., Elvaston Hall, Ryton-on-Tyne ... ... (E E) Dec. 1887
Parsons, Harry F., 5, Holmside Place, Heaton, Newcastle-on-Tyne (E) Dec. 1890
Pascoe, J. R., Tyrmont, Woodford, Essex (*Life Member*) ... ... (S) Dec. 1889
Paton, Alexander Robert, Lloyd's Register of Shipping, West Hartlepool ... ... (SUR) Dec. 1891
Patterson, Jas., West Lodge, Wallsend-on-Tyne ... ... (E) Nov. 1884
Pattison, Jos., c/o J. H. Hallett, Esq., 115, Bute Docks, Cardiff ... (E) Nov. 1884
Paulson, John, The Wm. Cramp & Sons' Ship and Engine Building Co., Philadelphia, U.S.A. ... ... (S) Feb. 1886
Peacock, Nicholas B. J., 30, Dingle Road, Tranmere Park, Birkenhead ... ... (E) Oct. 1892
Penney, R. H., Board of Trade Offices, St. Katharine's Dock House, Tower Hill, London, W. ... ... (S SUR) Nov. 1884
Pepper, W., Sunnyside, West Villas, Oxbridge Lane, Stockton-on-Tees .. .. (E) Nov. 1888
Petersen, John L., 18, Bellerby Terrace, West Hartlepool ... ... (E) Oct. 1888
Petree, James, c/o Messrs. Laird Bros., Birkenhead ... ... (S) Oct. 1885
Petrini, Giacomo Luigi, C.E., c/o Messrs. Gio Ansaldo & Co., Sestri-Ponente, Italy ... ... (N A) Nov. 1892
Petterson, Carl Edwin, 7, Vestra Hamngaten, Gothenburg, Sweden (E) Oct. 1891
Philipson, Roland, Tynemouth ... ... (E) Dec. 1884
Phillips, Walter, 79, Mark Lane, London, E.C. ... ... (N A & E) Oct. 1886
Phorson, P., 86, Roker Avenue, Sunderland ... ... (S) Nov. 1884
Piaud, Leon, Bureau Veritas, 8, Place de la Bourse, Paris ... ... (N A) Nov. 1888
Pitt, Frederick William, 15, Wilberforce Terrace, Gateshead-on-Tyne ... ... (E SUR) Oct. 1890
Plotnicki, E. C., 18, Frank Place, North Shields ... ... (E) Nov. 1886
Poli, Rodolfo, Chioggia, Italy ... ... (N A) Jan. 1890

ELECTED.

Pool, Frank, 64, Upper Alma Street, Newport, Monmouthshire ... (S) Mar. 1892
Potts, Matthew, 86, Glen Terrace, Hebburn-on-Tyne ... ... (S) Dec. 1890
Potts, Robert, 11, Mount Pleasant, Deptford, Sunderland ... ... (S) Oct. 1888
Price, F. D., 2, Bede Burn Street, Jarrow-on-Tyne ... ... (E & S) Oct. 1888
Price, John, 6, Osborne Villas, Jesmond, Newcastle-on-Tyne ... (S) Nov. 1884
Prince, Alfred, Kent Villa, Jarrow-on-Tyne ... ... (E) Nov. 1884
Pringle, James G., 10, Somerset Terrace, Walker-on-Tyne ... ... (S) Oct. 1892
Proud, Anthony, Tyne Docks, South Shields ... ... (E) Dec. 1888
Purdon, Andrew S., Fairfield Works, Govan, Glasgow ... ... (S) Oct. 1892
Purves, David, Wyborne Gate, Westcliffe Road, Birkdale, Southport ... ...(SUR) Dec. 1885
Purvis, Fred. W., 2, Cambridge Road, West Hartlepool ... ... (S) April 1893
Putnam, T., Darlington Forge, Darlington ... ...(F M) Nov. 1884
Putnam, William, Darlington Forge, Darlington ... ...(F M) Nov. 1884

Q.

Quicke, Herbert John, Summerhill House, Blaydon-on-Tyne ... (E) Feb. 1891

R.

Rae, John, 4, Grey Street, Glasgow, N.B. ... ... (E) April 1886
Ralston, G. C. ... ... (E) Oct. 1887
Ramage, J. T., c/o Mrs. Gibb, 74, Park Terrace, Hebburn-on-Tyne ... (E) April 1887
Ramage, John Anderson, 74, Park Terrace, Hebburn-on-Tyne ... (S) Oct. 1892
Rankine, Jno. ... ... (E) Nov. 1884
Readhead, Jas., Beach View, South Shields ... ... (S) Nov. 1884
Readhead, John, Jun., 4, Salisbury Place, South Shields ... ... (E) Mar. 1886
Readhead, R., 28, Sea View Terrace, South Shields ... ... (E) Nov. 1884
Readhead, W. B., South-garth, Westoe, South Shields ... ... (S) Nov. 1886
Reavell, W., c/o Messrs. Babcock & Wilcox, 114, Newgate Street, London, E.C. ... ... (E) { Graduate, April 1885; Member, Oct. 1887
Reed, Joseph, Angerton House, North Shields ... ... (E) Oct. 1889
Reed, J. W., c/o Messrs. Palmer's Shipbuilding and Iron Co., Limited, Engine Works Department, Jarrow-on-Tyne ... (E) Nov. 1884
Rennoldson, C., Messrs. J. P. Rennoldson & Sons, South Shields ... (S) Jan. 1886
Rennoldson, Jos. M., Messrs. J. P. Rennoldson & Sons, South Shields (S) Feb. 1886
Reynolds, Charles H., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Walker-on-Tyne ... ... (S) Mar. 1889
Reynolds, Edward, c/o Messrs. Vickers, Sons, & Co., Sheffield ... (E) Jan. 1888
Reynolds, W. G., 36, Meldon Terrace, South Shields ... ... (E) Oct. 1886
Richardson, Philip Wigham, Neptune Works, Walker-on-Tyne ... (S) Nov. 1890
Richardson, T., Jun., Hartlepool Engine Works, Hartlepool ... (E) April 1888
Richardson, Wigham, Neptune Works, Walker-on-Tyne ... ... (S) Nov. 1884
Rickaby, A. A., Bloomfield Engine Works, Sunderland ... ... (E) Mar. 1888
Ridley, J. H., Messrs. R. & W. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Nov. 1884
Riley, J. H., Messrs. Riley Bros., Stockton-on-Tees ... ... (B B) May 1893
Rimmington, R. F., 6, Cliff Terrace, Hartlepool ... ... (E) Nov. 1888
Ritson, M., Lloyd's Register of Shipping, 2, White Lion Court, Cornhill, London, E.C. ... ... (E SUR) Nov. 1884
Roberts, David, 19, West Avenue, Gosforth, Newcastle-on-Tyne... (E) Oct. 1891

ELECTED.

Robinson, B. A., 12, Harold Street, Sunderland ... ... (E) Nov. 1884
Robinson, William, 7, Choppington Street, Newcastle-on-Tyne ... ... (E) {Graduate, May 1885 / Member, April 1888}
Robson, Arthur, Messrs. J. Blumer & Co., Sunderland ... ... (S) Dec. 1886
Robson, George, 9, Wellington Terrace, South Shields ... ... (E) Oct. 1889
Robson, John H., Engineering Department, Sociedad Anonima, Astilleros del Nervion, Bilbao, Spain ... ... (E) Nov. 1885
Robson, J. M., c/o W. Whyte, B, Lombard Street, Newcastle-on-Tyne ... ... (E) Nov. 1884
Robson, M., 19, Zion Terrace, Newcastle Road, Sunderland ... (S) Nov. 1884
Roger, Robert, Stockton Iron Foundry, West Row, Stockton-on-Tees (E) Nov. 1888
Rogers, Herbert M., Laurel Bank, Bromley Common, Kent (SUR) April 1889
Rolf, George, Lefroy House, Newcastle-on-Tyne ... ... (E E) May 1892
Rolland, Alexander, Casa Absle, via Pomerio, Fiume, Hungary ... (E) Mar. 1892
Rooke, Charles Bowden, Jun., St. Paul's Road, West Hartlepool ... (E) Nov. 1889
Ropner, Robert, Jun., Preston Hall, Stockton-on-Tees ... ... (S) Feb. 1886
Rose, Joseph, Rose Hill, Howdon-on-Tyne ... ... (E) Oct. 1891
Ross, William, 20, Meadow Side, Dundee ... ... (E) May 1893
Rowan, Jas., 231, Elliott Street, Glasgow ... ... (E) Nov. 1886
Rowell, G. W., Simla House, New Benwell, Newcastle-on-Tyne ... (E) Feb. 1885
Rowell, H., 45, Glen Terrace, Hebburn-on-Tyne ... ... (S) Nov. 1884
Rusden, L., 14, Sanderson Road, Jesmond, Newcastle-on-Tyne ... (E) Nov. 1884
Russell, F. Herbert, 3, Victoria Crescent, Cullercoats ... ... (E) Oct. 1891
Rutherford, G., Bute Dry Dock, Roath Basin, Cardiff ... ... (S) Oct. 1886
Ruthven, M. W., c/o Messrs. J. M. Lennard & Sons, Middlesborough (SUR) Nov. 1891
Ryder, C. L., 63, Bute Street, Cardiff ... ... (E) Oct. 1886
Ryder, William J. H., 4, Graingerville, Newcastle-on-Tyne ... (E) Oct. 1891

S.

Salmon, P., 5, The Oaks West, Sunderland ... ... (E SUR) Nov. 1884
Sambidge, James, c/o Messrs. J. H. Holmes & Co., Portland Road, Newcastle-on-Tyne ... ... (E E) Nov. 1891
Sandeman, John Watt, 2, St. Nicholas' Buildings, Newcastle-on-Tyne ... ... (E) Oct. 1891
Sanderson, Henry Thomas Barron, Messrs. Sanderson & Co., High Quay, Blyth... ... ... (E) Oct. 1891
Sanderson, J., 31, Park Road, Jarrow-on-Tyne ... ... (S) Nov. 1884
Sandison, M., Elswick Shipyard, Newcastle-on-Tyne ... ... (E) Dec. 1884
Sawyers, John, c/o Messrs. Thos. Wilson, Sons, & Co., Hull ... (E) Oct. 1886
Schaeffer, A. G., 4, Benton Terrace, Newcastle-on-Tyne ... ... (E) Nov. 1884
Scorer, G. S., c/o Messrs. T. & W. Smith, North Shields ... ... (S) Jan. 1885
Scotson, Alf., 22, Victoria Road, Middlesborough ... ... (S) Feb. 1887
Scotson, Wm., 78, Stafford Street, Wednesbury ... ... (E) Nov. 1884
Scott, Ernest, Close Engine Works, Newcastle-on-Tyne ... ... (E E) Nov. 1884
Scott, George Innes, Three Indian Kings' Court, Quayside, Newcastle-on-Tyne ... ... (E) Oct. 1889
Scott, James, c/o Messrs. Consett Iron Co., Blackhill, Co. Durham... (E) Oct. 1892
Scott, Joseph R., 9, Queen Street, Newcastle-on-Tyne ... ... (E) Oct. 1887
Scott, William, 2, Clifton Terrace, Alnwick ... ... (E) Nov. 1884
Scurlock, Thos. Henry, Elmwood, Barry, near Cardiff ... ... (S) Oct. 1890
Seabury, Edward, 40, West India Road, Limehouse, London, E. ... (E) Mar. 1886

		ELECTED.
Seaman, C. J., 8, Victoria Terrace, Stockton-on-Tees	(E)	Jan. 1889
Seaton, Albert Edward, Messrs. Earle's Shipbuilding Co., Hull ...	(E)	Jan. 1891
Selby, Thomas, 7, Regent Square, Hartlepool	(E)	Nov. 1891
Sells, C. Degrave, Cornigliano, Ligure, Italy	(E)	Oct. 1887
Shand, H., 41, Grosvenor Place, West Jesmond, Newcastle-on-Tyne	(E)	Nov. 1884
Sharp, A. E., 4, Bede Burn Road, Jarrow-on-Tyne	(E)	Nov. 1884
Sharp, Mark, 144, Albert Road, Jarrow-on-Tyne	(E)	Dec. 1889
Sharpe, H. R.	(E)	Nov. 1888
Shaw, Jas., 17, Normanby Terrace, Gateshead-on-Tyne	(E)	Jan. 1885
Sheriff, Thomas, c/o Messrs. Robert Mackill & Co., 29, Waterloo Street, Glasgow	(E)	April 1890
Shevill, W. H., 5, Avenue Terrace, Sunderland	(E)	Nov. 1884
Short, J. Y., 49, West Sunniside, Sunderland	(S)	Nov. 1884
Short, Jos., 49, West Sunniside, Sunderland	(S)	Nov. 1884
Shotton, John W., 32, Mount Stuart Square, Cardiff	(SUR)	Nov. 1886
Shute, A. E., 248, Burley Mount, Leeds	(E)	Dec. 1892
Simpson, Edward, 2, Neptune Road, Wallsend-on-Tyne	(S)	Dec. 1890
Sinclair, R., c/o Messrs. J. Wildridge & Sinclair, Consulting Engineers, 97, Pitt Street, Sydney, N.S.W., Australia ...	(E)	Nov. 1884
Sinton, John K., 26, Sandhill, Newcastle-on-Tyne	(E)	Nov. 1885
Sisson, Wm., Gloucester	(E & N A)	Oct. 1888
Sisterson, G. R., Locomotive Department, London and South Western Railway, Nine Elms, London, S.W.	(E)	Nov. 1884
Sivewright, G. W., 5, Radcliffe Terrace, Hartlepool	(S)	Nov. 1886
Skinner, Leslie, Ravensbourne Terrace, South Shields	(S)	Graduate, Dec. 1886 Member, Oct. 1891
Smith, C. E., 73, Thornton Street, West Hartlepool	(E)	Nov. 1888
Smith, Eustace, 5, Queen Street, Newcastle-on-Tyne	(S)	Nov. 1884
Smith, John Law, West Hartlepool Steel and Iron Works, West Hartlepool	(I & S M)	May 1893
Smith, Malden H., Los Astilleros del Nervion, Bilbao, Spain ...	(S)	April 1893
Smith, R. J., Pier Engine Works, South Dock, Sunderland ...	(E)	Nov. 1884
Smith, Reginald Thomas, South African College, Capetown ...	(E)	April 1888
Smith, Thomas, Steam Crane Works, Old Foundry, Rodley, near Leeds	(E)	Oct. 1888
Smith, Thomas Edward, Messrs. John Smith & Sons, Newgate Street, Newcastle-on-Tyne	(E)	April 1885
Smith, Wm., 51, Dock Street East, Sunderland	(E)	Nov. 1884
Soliani, Nabor, Connitato Pei Designa delle Navi Ministero dilla Marina, Roma, Italy	(S)	Jan. 1885
Soulsby, J. C., Dowlais Chambers, West Bute Street, Cardiff	(SUR)	Nov. 1886
Sowter, Isaac G., 867, East Congress Street, Detroit, Michigan, U.S.A.	(E)	Jan. 1889
Spear, John, c/o Messrs. T. Wilson & Sons, Hull	(E)	Oct. 1887
Spearman, Richard, 13, Fransfield Grove, Sydenham, London ...	(E)	Feb. 1889
Spence, W. G., c/o George Clark, Esq., Southwick Engine Works, Sunderland (*Life Member*)	(E)	Nov. 1884
Spencer, J. W., Newburn Steel Works, Newburn-on-Tyne ...	(E)	Feb. 1885
Stafford, William, Dunston-on-Tyne	(E)	Nov. 1885
Stansfield, George R., 4, Beaconsfield St., Westoe, South Shields...	(E)	Mar. 1891
Stephenson, C., 2, Elm Terrace, The Green, Wallsend-on-Tyne ...	(S)	Nov. 1884
Stevenson, Wm., 6, West View, Wallsend-on-Tyne	(E)	Nov. 1884

ELECTED.

Stewart, James, 31, Lily Avenue, Jesmond, Newcastle-on-Tyne .. (E) Oct. 1890
Stirling, Andrew, Jun., 1, Greenvale Terrace, Dumbarton ... ... (E) Feb. 1888
Stirzaker, J. C., 16, Grosvenor Place, Newcastle-on-Tyne ... ... (E) Nov. 1884
Stoddart, J. E., Lloyd's Register of Shipping, Dock Office, West Hartlepool ... ... (E SUR) Oct. 1888
Stoddart, Swinton, 24, North Milburn Street, Sunderland... ... (S) Nov. 1892
Stokoe, Thomas W., 4, Lower Archer Street, West Hartlepool ... (S) Dec. 1885
Stone, Wm., 13, Rosslyn Terrace, Sunderland ... ... Nov. 1884
Stonehouse, Andrew, Jun., 28, Percy Terrace, Sunderland ... (S) Oct. 1890
Strong, George Aaron, 87, West Percy Street, North Shields ... (E) Dec. 1889
Summers, James, 114, Grange Road West, Middlesborough ... (E) Mar. 1889
Summersby, Robert Arthur, 4, Otterburn Terrace, Newcastle-on-Tyne ... ... (E) Oct. 1891
Surtees, Francis V., Westbourne Street, Stockton-on-Tees... ... (S) Dec. 1892
Surtees, R., c/o Sociedad Anonima, Astilleros del Nervion, Bilbao, Spain ... ... (E) Nov. 1884
Sutcliffe, George William, 5, Norfolk Street, Manchester ... ... (E) Dec. 1891
Swan, A. S., Grove House, Gosforth, Newcastle-on-Tyne ... ... (S) Nov. 1888
Swan, H. F., Beaufront Castle, Hexham ... ... (S) Nov. 1884
Swan, Thomas, Mayfield House, Leslie, Fifeshire ... ... Nov. 1884
Swinburne, M. W., 117, Park Road, Newcastle-on-Tyne ... ... (E) Nov. 1884
Swinburne, T. M., Bewick Road, Gateshead-on-Tyne ... ... (E) Jan. 1885
Swinney, W., 10, Wentworth Terrace, Westoe Lane, South Shields (E) Dec. 1888
Sydserff, Thomas B., Jun., 3, South Parade, Kettering ... ... (E) Oct. 1888
Syme, James, Fairfield Works, Govan, Glasgow ... ... (E) Oct. 1892

T.

Tate, Chas. H., 7, Side, Newcastle-on-Tyne ... ... (N A) Nov. 1884
Tatham, Stanley, Montrose, Bromley Park, Bromley, Kent ... (E) Feb. 1887
Taylor, Alexander, Maritime Buildings, King Street, Newcastle-on-Tyne ... ... (E) Nov. 1884
Taylor, C. W., South Garth, Westoe, South Shields ... ... (E) April 1885
Terry, Stephen H., 17, Victoria Street, Westminster, S.W. ... (E) Oct. 1891
Thompson, C. E., Messrs. J. L. Thompson & Sons, Sunderland ... (S) Nov. 1884
Thompson, Charles, 9, Dean Street, Newcastle-on-Tyne ... ... (E) Feb. 1887
Thompson, Jas., 11, Elmwood Street, Sunderland ... ... (E) Dec. 1886
Thompson, John, Post Office Chambers, Newcastle-on-Tyne ... (C E) Nov. 1884
Thompson, John Augustus, 12, London Street, Fenchurch Street, London, E.C. ... ... (E & N A) Oct. 1892
Thompson, J. L., North Sands Shipyard, Sunderland ... ... (S) Nov. 1884
Thompson, Robert, North Sands Shipyard, Sunderland ... ... (S) Nov. 1884
Thomson, James, Jun., M.A., c/o Messrs. Sir W. G. Armstrong, Mitchell, & Co., Ordnance Works, Elswick, Newcastle-on-Tyne (E & N A) Nov. 1890
Thorn, W. H., 5, Waterville Terrace, North Shields ... ... (E) Nov. 1884
Thornton, James, Pullington Villa, Cumberland Road, Bristol ... (E) April 1893
Tinkler, Robert Harrison ... ... (E) April 1891
Tinn, Fred. D., 2, Sunningdale Terrace, South Shields ... ... Nov. 1891
Tinwell, George, General Gordon Terrace, Sunderland ... ... (E) Jan. 1889
Todd, Surtees, c/o Messrs. R. & W. Hawthorn, Leslie, & Co., Hebburn-on-Tyne ... ... (S) Nov. 1884
Todd, Thomas, 19, Billiter Street, London, E.C. ... ... (E) Nov. 1885

ELECTED.

Tone, John M. F., 50, Clayton Park Square, Newcastle-on-Tyne ... ... (E) Graduate, April 1885; Member, Oct. 1887

Topham, Henry George, c/o Miss Wood, 38, Grove Street, Newcastle-on-Tyne .. .. (E) May 1891

Towers, Edward, Jun., 4, Latimer Street, Tynemouth (E) Graduate, Nov. 1886; Member, Oct. 1888

Trail, John, 25, Sanderson Road, Jesmond, Newcastle-on-Tyne (M S) Oct. 1892

Trewent, F. J., 43, Billiter Buildings, Billiter Street, London, E.C. (S) Dec. 1884

Tritton, S. B., Highfield, The Avenue, Surbiton, Surrey ... ... (E) Nov. 1884

Tulip, George, 28, Henry Street, Hendon Road, Sunderland ... (E) Dec. 1888

Turner, S. J., 71, Warwick Street, Heaton, Newcastle-on-Tyne ... (E) Mar. 1887

Twaddell, James L., 100, Bede Burn Road, Jarrow-on-Tyne ... (S) Oct. 1891

Tweddell, R. H., Meopham Court, Gravesend, London ... ... (E) Jan. 1885

Tweedy, J., Neptune Works, Walker-on-Tyne ... ... (E) Nov. 1884

Twigden, George J., c/o Messrs. Hick Bros., Mount Stuart Square, Cardiff ... ... (E) Jan. 1890

Tyzack, George, Dean Street, South Shields ... ... (E) April 1888

U.

Ullstrom, Otto, Messrs. Crompton, Ullstrom, & Crompton, 19, Gracechurch Street, London, E.C. ... ... (S) Nov. 1884

Ulm, John, The Arsenal, Pola, Austria ... ... (E) Nov. 1885

V.

Vianson, N. E., *vid* Galeazzo Alessi 6 into 1, Genoa, Italy ... ... (E) Dec. 1885

Vick, R. W., Messrs. E. Withy & Co., West Hartlepool ... ... (S) Nov. 1888

Vivet, Leon, 12, Rue de Seine, Paris ... ... (N A) Nov. 1892

W.

Wadagaki, Yasuzo, c/o Messrs. Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Jan. 1891

Wailes, E. F., 4, St. Nicholas' Buildings, Newcastle-on-Tyne ... (N A) Nov. 1884

Wailes, T. W., Mount Stuart Dry Docks, Cardiff ... ... (E & S) Oct. 1887

Wake, Tom, Moor Terrace, Hartlepool ... ... (E) April 1892

Walker, Archibald, Elizafield House, North Fort Street, Leith, N.B. (E) April 1887

Walker, Henry, 11, Oxford Terrace, Gateshead-on-Tyne .. ... (E E) Feb. 1893

Walker, John, c/o Messrs. R. Stephenson & Co., Limited, South Street, Newcastle-on-Tyne ... ... (E & S) Nov. 1891

Wallau, J., c/o Messrs. Black, Hawthorn, & Co., Gateshead-on-Tyne (E) Nov. 1884

Walliker, J. F., 2, Lovaine Terrace, North Shields ... ... (E) Nov. 1885

Wallis, Robert, Point Pleasant House, Wallsend-on-Tyne ... ... (E) April 1891

Walter, Max, 120B, Smidtstr, Bremerhaven ... ... (S) Feb. 1893

Walton, J. G., 26, Fenchurch Street, London, E.C. ... ... (E) Nov. 1884

Warburton, J., 19, Lorne Terrace, Sunderland ... ... Nov. 1884

Ward, John, c/o Messrs. W. Denny & Bros., Dumbarton ... ... (S) Dec. 1891

Wardale, Henry, 5, Collingwood Terrace, Gateshead-on-Tyne ... (E) Feb. 1888

Watt, Robert B., c/o Messrs. Raylton Dixon & Co., Middlesborough (S) April 1888

Watts, Philip, Elswick Shipyard, Newcastle-on-Tyne ... ... (S) Nov. 1885

Waugh, G. W., 3, Lovaine Avenue, North Shields ... ... (E) May 1885

Weatherall, J., c/o Messrs. Naval Construction & Armaments Co., Barrow-in-Furness ... ... (E) Graduate, Oct. 1885; Member, Oct. 1887

ELECTED.

Weidemann, Nils, Det-Norske Veritas, Christiania, Norway ...(SUR) Jan. 1892
Weighton, R. L., M.A., Durham College of Science, Barras Bridge, Newcastle-on-Tyne ... ... (E) Nov. 1884
Weinberg, Herbert Jas., 14, Guillaume Terrace, Southampton ... (E) Nov. 1892
Weir, John, c/o Messrs. J. Scott & Co., Abden Works, Kinghorn, N.B. ... ... (E) Nov. 1884
Weir, William, c/o Messrs. Wigham Richardson & Co., Walker-on-Tyne ... ... (E) Nov. 1889
West, Henry H., 14, Castle Street, Liverpool ... ... (E & N A) Oct. 1886
Westgarth, Tom, Messrs. Westgarth, English, & Co., Middlesborough (E) Oct. 1886
Westmacott, Alfred, Benwell Hill, Newcastle-on-Tyne ... ... (E) Nov. 1892
Westmacott, P. G. B., Benwell Hill, Newcastle-on-Tyne ... ... (E) Nov. 1884
White, C., 13, Mosley Street, Newcastle-on-Tyne ... ... (E) Nov. 1884
White, R. S., Fairfield Works, Govan, Glasgow ... ... (S) Nov. 1884
Whittaker, Frederick W., c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness ... ... (E) Oct. 1892
Whyte, Wm., B, Lombard Street, Newcastle-on-Tyne ... ... (E) Nov. 1884
Widdas, T. D., 246, Newport Road, Cardiff ... ... (SUR) April 1885
Wilkie, J., 24, Camden Street, Southwick, Sunderland ... ... (E) Nov. 1884
Willcox, F. W., 45, Sunniside West, Sunderland ... ... (E) Nov. 1884
Williams, T. Fitzroy, 17, Landsdowne Terrace, Gosforth, Newcastle-on-Tyne ... ... (E) Feb. 1890
Wilson, J. T., Spennymoor House, Spennymoor ... (E) {Graduate, April 1885 / Member, Feb. 1886}
Wilson, James Edmund, 58, Forster Street, Monkwearmouth ... (S) Nov. 1892
Winstanley, P. D., Bureau Veritas, 155, Fenchurch Street, London (S) Nov. 1884
Wisnom, Hugh, 107, Fitzroy Avenue, Belfast ... ... (E) Oct. 1890
Withy, H., Middleton Shipyard, West Hartlepool ... ... (S) Nov. 1884
Worsdell, Wilson, North-Eastern Locomotive Works, Gateshead-on-Tyne ... ... (E) Dec. 1888
Wortley, Henry B., 23, Bedford Road, Rock Ferry, Birkenhead ... (S) Nov. 1892
Wotherspoon R., Board of Trade Offices, West Hartlepool... (E SUR) April 1889
Wright, R., 5, Hawthorn Terrace, Newcastle-on-Tyne ... ... (E) Nov. 1884

Y.

Young, Andrew, 70, Falmouth Road, Heaton, Newcastle-on-Tyne (S) May 1893
Young, J. Denholm, 11, Grange Crescent, Sunderland ... ... (E) Oct. 1888
Younger, R., Elmire House, Heaton, Newcastle-on-Tyne ... ... (E) Nov. 1884

Z.

Zeeman, J. H., c/o Messrs. The Maas Co., Rotterdam ... ... (S) Oct. 1889
Zeltz, A., Actien Gesellschaft, Weser-in-Bremen ... ... (E) Nov. 1884

ASSOCIATES.

A.

Armstrong, S., 14, Victoria Place, Hartlepool ... ... (A) Nov. 1888

B.

Bacon, William Charles, Chadwick House, West Hartlepool ...(S O) Dec. 1890
Barklam, George, 167, Dudley Port, Tipton, Staffordshire ... (A) April 1888
Barraclough, Thomas, West Hartlepool Steam Navigation Co., West Hartlepool ... ...(S O) Dec. 1890

ELECTED.

Barwick, J. S., Ashbrook Grange, Sunderland ... ... (S O) Nov. 1884
Bell, John Henry, 3, Kensington Esplanade, Sunderland ... (I & S M) Oct. 1887
Beynon, Thomas, 9, Dean Street, Newcastle-on-Tyne ... ... (E A) Oct. 1891
Bigge, C. W., Northern Counties Club, Newcastle-on-Tyne ... (A) Dec. 1889
Blacklin, Richard James, Dinsdale House, Brougham Terrace, West Hartlepool ... ... (S O) Dec. 1890
Branfoot, W. J., Messrs. Tyzack & Branfoot, 18, John Street, Sunderland ... ... (S O) Dec. 1887
Briggs, R. S., Moorlands, Sunderland ... ... (S O) Dec. 1886
Brunton, John, 3, Prior's Terrace, Tynemouth ... ... (S O) Oct. 1886
Bullen, Tempest C., c/o Messrs. H. E. Moss & Co., K, Exchange Buildings, Newcastle-on-Tyne ... ... (S O) Nov. 1891

C.

Carnegy, Robert B., c/o Messrs. De Beers Consolidated Mine Co., Kimberley, South Africa... ... ... (A) Oct. 1891
Carr, Ralph, Thornleigh, Clayton Road, Newcastle-on-Tyne (A & S O) Nov. 1886
Cassap, William, 15, East Field Road, Walthamstow, Essex ...(SUR) Feb. 1890
Caws, Frank, 22, Fawcett Street, Sunderland ... ... (C E) Oct. 1892
Cohan, Edward Asher, 2, Rumford Place, Liverpool ... ... (S O) Nov. 1889
Common. Francis James, 5, Elms West, Sunderland ... (I & S M) Oct. 1887
Conner, L. R., Exchange, West Hartlepool ... ... (S O) Jan. 1891
Cooper, Charles, Average Adjuster, Wellington Road, West Hartlepool ... ... (A A) April 1893
Corbitt, Michael, 1, Abbotsford Terrace, Newcastle-on-Tyne ... (R M) Jan. 1890
Coull, John, 43, Stanley Street West, North Shields ... ... (S O) Oct. 1886
Coverdale, R. H., Messrs. J. Coverdale & Sons, Steamship Owners, West Hartlepool ... ... (S O) Nov. 1888
Crosier, Edward James, 3, The Hawthorns, East Boldon ... ... (A) Oct. 1889
Crowther, Joseph, Dispensary Lane, Newcastle-on-Tyne ... ... (I M) Jan. 1889
Culliford, J. H. W., 45, West Sunniside, Sunderland ... ... (S O) Nov. 1884

D.

Dodds, A. P., 13, Dean Street, Newcastle-on-Tyne ... ... (A) Jan. 1889
Dodds, Charles Henry, General Manager, River Wear Commission, 16, Thornhill Terrace, Sunderland ... ... Oct. 1887
Dodds, John B., 36, Side, Newcastle-on-Tyne ... ... (CHEM) Oct. 1888
Dove, Edward John, 5, St. Nicholas' Buildings, Newcastle-on-Tyne Oct. 1890

E.

Eccles, Edward, G, Exchange Buildings, King Street, Newcastle-on-Tyne (*Life Associate*) ... ... (S O) Oct. 1887

F.

Furness, Christopher, M.P., Victoria Terrace, West Hartlepool ... (S O) Oct. 1888

G.

Garnett, William, Principal, The Durham College of Science, Newcastle-on-Tyne ... ... Jan. 1889
Graham, Frank, Bank Chambers, Mosley Street, Newcastle-on-Tyne ... ... (E A) Nov. 1891
Greenwell, Thos. G., Sunderland ... ... (S O) Dec. 1886

H.

ELECTED.

Harland, George, 1, Westoe Crescent, South Shields ... ... (A) Dec. 1888
Hedley, John H., 10, Esplanade West, Sunderland ... ... (S) Dec. 1886
Heslop, Richard O., Akenside Hill, Newcastle-on-Tyne ... (I & S M) Oct. 1885
Hogg, George J. H., N.E.C. Insurance Association, West Hartlepool (S O) Oct. 1888
Hollis, H. E., 3, St. George's Terrace, Jesmond, Newcastle-on-Tyne (I & S M) Feb. 1885
Hudson, Ralph M., Jun., 8, The Cedars, Sunderland ... ... (S O) Dec. 1886
Hunting, Charles, 1, Exchange Buildings, Quayside, Newcastle-on-Tyne ... ... (S O) April 1886

I.

Innes, Charles H., Engineering Lecturer, School of Science and Art, 21, Beverley Terrace, Cullercoats ... ... (E) Oct. 1891

J.

Jenkins, William, Consett Hall, Durhamshire ... ... (I & S M) Nov. 1887
Jobson, W. J., c/o Messrs. Robert Stephenson & Co., South Street, Newcastle-on-Tyne ... ... (A) May 1889
Jordan, John George, 24, Stansfield Street, Sunderland ... ... (A) Nov. 1892

K.

Kerr, James, 18, Azalea Terrace South, Sunderland ... ... (A) Jan. 1888

L.

Lennard, William, c/o Messrs. J. M. Lennard & Sons, Middlesborough ... ... (S) Dec. 1891
Lockie, John, 4, Sanderson Road, West Jesmond, Newcastle-on-Tyne ... ... (S O) Oct. 1892
Loveridge, W. H., Albert Terrace, West Hartlepool... ... (I & S M) Oct. 1888

M.

Macarthy, George E., 9, Dean Street, Newcastle-on-Tyne ... ...(S O) Oct. 1887
Matthiessen, P. H., 25, Queen Street, Newcastle-on-Tyne ... ...(S O) Oct. 1888
Maughan, William, 13, Mosley Street, Newcastle-on-Tyne... ... (A) Feb. 1887
Mawson, Rowland, Bank Chambers, Quay, Newcastle-on-Tyne ... (S O) Jan. 1889
McIntosh, R. Y., 53, Quayside, Newcastle-on-Tyne ... ... (E A) Nov. 1891
McIntyre, John, 3, Abbotsford Terrace, Newcastle-on-Tyne ... (S O) Jan. 1885
Metcalf, Thomas, 18, John Street, Sunderland ... ...(SUR) Jan. 1888
Milburn, J. D., Queen Street, Newcastle-on-Tyne ... ... (S O) Nov. 1884
Miller, T. R., c/o Messrs. Lamplough & Co., 72, Cornhill, London ... ... (A & S O) Nov. 1884
Mitcalfe, John Stanley, Chairman of Northern Maritime Insurance Co., Maritime Buildings, Newcastle-on-Tyne ... ... (A & S O) Jan. 1892
Mulherion, G. F., 13, Argyle Street, Tynemouth ... ... (A) Nov. 1884
Muller, J. C. F., 28, Vieille Route, Antwerp ... ...(SUR) Feb. 1890

N.

Newby, S., c/o Messrs. Thomson & Newby, 42, West Sunniside, Sunderland... ... ... (I & S M) Nov. 1884
Nicholson, John, Marine Superintendent, 7, Side, Newcastle-on-Tyne... ... ... (M S) Nov. 1890
Nicol, Andrew, 22, Grosvenor Road, Jesmond, Newcastle-on-Tyne (S) Oct. 1891

O.

		ELECTED.
O'Hagan, James, St. Nazaire-sur-Loire, France	(A)	Oct. 1888
Olsen, Hans Benedick, 70, Church Street, West Hartlepool ...	(S O)	Mar. 1893
Osbourne, Jas., 11, The Oaks, Sunderland	(S)	Jan. 1885

P.

Panton, Hugh, 38, Fawcett Street, Sunderland	(I & S M)	Nov. 1887
Patterson, Thos., 2, The Elms, Sunderland	(S)	Jan. 1885
Pattison, W. J., 32, Great St. Helen's, London	(S O)	April 1886
Perry, Edwin, Queen Street, Newcastle-on-Tyne	(A)	Nov. 1885
Phalp, Oliver, Almora, 37, Richmond Road, Cardiff...	(SUR)	Feb. 1889
Pinkney, Thomas, 3, Ashbrook Terrace, Sunderland	(S O)	Dec. 1886
Pirrie, Robert Reid, Baltic Chambers, Quayside, Newcastle-on-Tyne	(S O)	Dec. 1889

R.

Radloff, Capt. O., Marine Superintendent, S.S. "Saratov," Russian Volunteer Fleet Agency, Odessa, Russia	(M S)	Nov. 1891
Ramsay, J. W., 13, Northbrook Road, Lee, Kent	(A)	Feb. 1885
Reichwald, A., Lombard Street, Newcastle-on-Tyne	(A)	Nov. 1884
Reid, Andrew, Printer, Akenside Hill, Newcastle-on-Tyne ...		Nov. 1884
Renwick, G., Messrs. Fisher, Renwick, & Co., Queen Street, Newcastle-on-Tyne	(S O)	Nov. 1884
Rickinson, John, 9, Church Street, West Hartlepool	(S O)	Nov. 1890
Robson, Frederick, 46, Dean Street, Newcastle-on-Tyne ...	(S I M)	Oct. 1887
Robson, Thos., Causeway House, Sunderland	(S O)	Nov. 1884
Runcieman, John Finley, 38, Larkspur Terrace, Jesmond, Newcastle-on-Tyne	(M S)	Nov. 1892

S.

Scholefield, A., 17, Sandhill, Newcastle-on-Tyne	(S O)	Nov. 1884
Scott, W. H., Messrs. Scott Brothers, Dean St., Newcastle-on-Tyne	(S O)	Nov. 1884
Snowdon, W. F., 32, Side, Newcastle-on-Tyne	(E A)	Dec. 1886
Squance, J. W., Marine Superintendent, 13, The Avenue, Sunderland	(M S)	April 1888
Swan, Isaac J., Grove House, Gosforth, Newcastle-on-Tyne ...	(S O)	Feb. 1888

T.

Temperley, C., 9, Gracechurch Street, London	(S O)	Nov. 1885
Thompson, V. T., Baltic Chambers, Sunderland	(S O)	Dec. 1886
Towers, Edward, 4, Latimer Street, Tynemouth	(A)	Oct. 1888

W.

Wait, James, Maritime Buildings, King Street, Newcastle-on-Tyne	(S O)	Nov. 1884
Wait, John, 70, Broughton Road, South Shields	(A)	Oct. 1891
Wallace, Wm., 27, South Scarborough Street, West Hartlepool ...	(A)	Oct. 1888
Ward, Joseph, Rosehill, Howdon-on-Tyne	(A)	Nov. 1886
Watson, Thomas W., Marine Superintendent, Gisburn House, Hartlepool	(M S)	Nov. 1890
Weatheral, Henry, 27, Alderson Street, West Hartlepool	(A)	Feb. 1893
Welford, Richard, Gosforth, Newcastle-on-Tyne	(S O)	April 1888

Y.

Yeoman, F., Messrs. Murrell & Yeoman, West Hartlepool ...	(S O)	Nov. 1888
Young, William M., Guildhall Chambers, Newcastle-on-Tyne ...	(S O)	Mar. 1889
Younger, Robert Laurie, Messrs. Greenock Steamship Co., Limited, Greenock	(A)	Feb. 1889

GRADUATES.

A.

	ELECTED.
Adams, Cecil Turner, 1, Race Street, Newcastle-on-Tyne	(E) Oct. 1891
Adamson, Daniel, c/o Messrs. Joseph Adamson & Co., Hyde ...	(E) Feb. 1888
Anderson, John, 13, Amberley Street, Sunderland	(E) Oct. 1891
Andrew, David, Jun., 33, Osborne Road, Newcastle-on-Tyne ...	(E) Oct. 1891
Armstrong, Wm. S., 63, Croft Terrace, Jarrow-on-Tyne	(S) Oct. 1892

B.

Baker, Ernest, c/o Messrs. The Wallsend Slipway and Engineering Co., Wallsend-on-Tyne	(E) Nov. 1892
Barbour, John, 1, Logan Terrace, South Shields	(E) Nov. 1890
Beale, Harry, Otterburn Villas, Newcastle-on-Tyne	(S) Jan. 1891
Bell, George Arthur, 29, Hawthorn Street, Newcastle-on-Tyne ...	(E) Oct. 1890
Bentham, Frederick Lister, 9, Bellegrove Terrace, Newcastle-on-Tyne...	(E) Dec. 1892
Bilbrough, Kenneth L., 50, The Avenue, Wallsend-on-Tyne ...	(E) Nov. 1891
Boyd, William, Jun., North House, Long Benton, Newcastle-on-Tyne...	(E) Nov. 1887
Brodin, Olof, Ecfle, Sweden	(S) Mar. 1890
Brown, William Frank, Dawson Square, Tynemouth	(E) Mar. 1891
Bryers, Charles, 10, The Avenue, Sunderland	(E) Dec. 1892
Burnett, Jacob Edward, 10, Prior's Terrace, Tynemouth	(E) Oct. 1891

C.

Cadman, C. C., 21, Shieldfield Green, Newcastle-on-Tyne	(E) Nov. 1891
Calvert, T. Horsfall, 126, Church Street, Walker-on-Tyne... ...	(E) Nov. 1891
Carpmael, Richard Herbert, 54, Maple Street, Newcastle-on-Tyne	(E) Jan. 1893
Carter, Thomas, Jun., 29, North Bridge Street, Sunderland ...	(E) Nov. 1891
Clague, James Henry, Birkenhead Iron Works, Birkenhead ...	(S) April 1891
Clarke, John H., 5, Gordon Terrace, Southwick, Sunderland ...	(E) Jan. 1893
Coatsworth, George S., 1, Humbleton View, Sunderland	(E) Nov. 1891
Coleby, James William, Boundary Street, Willington Quay-on-Tyne	(E) Oct. 1891
Cooper, Arthur, Messrs. Scott, Mountain, & Co., Close, Newcastle-on-Tyne	(E E) Mar. 1891
Cooper, William, Jun., 11, Ridley Place, Newcastle-on-Tyne ...	(E) Nov. 1890
Coopor, Sidney, 14, Northgate, Hartlepool	(E) Nov. 1891
Coull, Alex. B., 43, Stanley Street W., North Shields	(E) Feb. 1887
Cowan, David, 22, Clarendon Terrace, South Shields	(S) Nov. 1890
Creighton, Alexander, 31, George's Road, Newcastle-on-Tyne ...	(S) Dec. 1892

D.

Davis, James Albert, 4, Dickinson Crescent, Gosforth, Newcastle-on-Tyne	(S) Dec. 1892
Davis, Thomas Wilfred, Birkenfeld, Bromley, Kent	(E) Jan. 1891
Davison, William H. G., 49, Sanderson Road, West Jesmond, Newcastle-on-Tyne	(E) Dec. 1892
Dobson, Henry James, c/o Messrs. William Dobson & Co., Walker-on-Tyne, R.S.O.	(S) Oct. 1891
Donkin, Samuel, 5, Dean Terrace, Southwick, Sunderland ...	(E) Jan. 1888
Donovan, John, 5, Ash Place, Sunderland	(E) Dec. 1892

ELECTED.

Doxford, Albert Ernest, B.A., West Lawn, Sunderland ... ... (E) Oct. 1890
Duckitt, J. Brentnall, Leazes Gate Villa, Spital Tongues, Newcastle-on-Tyne ... ... (E) Oct. 1888
Duckitt, Talbot, Leazes Gate Villa, Spital Tongues, Newcastle-on-Tyne ... ... (E E) Oct. 1891

E.

Elder, Edward, Loudon House, Jarrow-on-Tyne ... ... (S) Nov. 1890
Evers, Ernest Henry, 7, Bentinck Crescent, Newcastle-on-Tyne ... (S) Dec. 1892
Ewen, Alexander, St. Mary's Island, Whitley-by-the-Sea ... ... (E) Oct. 1891

F.

Fairbairn, Jas., Hendon Valley Road, Sunderland ... ... (E) May 1885
Finch. Herbert K., c/o Hawthorn, Leslie, & Co., St. Peter's, Newcastle-on-Tyne ... ... (E) Dec. 1888
Foley, Wm. C. le B., 12, Grove Street, Newcastle-on-Tyne ... (S) Nov. 1887
Forster, Alfred L., 28, Fraser Terrace, Gateshead-on-Tyne ... (E) Nov. 1891
Freeman, Alfred I., 2, Regent Terrace, Newcastle-on-Tyne ... (E) Dec. 1890

G.

Gaine, Roger L., 17, Park Place E., Sunderland ... ... (E) Dec. 1887
Gibson, Joseph H., 53, Hemans Street, Liverpool ... ... (E) April 1891
Golledge, W., High Street, Warkworth ... ... (E) Nov. 1891

H.

Hamilton, Robert C., 2, Dene Crescent, Walker-on-Tyne, R.S.O.... (E) Dec. 1892
Hardy. Arthur. 5, Warwick Place, Newcastle-on-Tyne ... ... (E) Dec. 1892
Henshall. Samuel, c/o Messrs. W. Harkess & Son, Shipbuilders, Middlesbrough ... ... (S) May 1885
Hewitt, John, 29, Holly Street, Jarrow-on-Tyne ... ... (S) Nov. 1890

J.

Jannings, Frank, 6, South Terrace, Southwick, Sunderland ... (E) Mar. 1892
Johnson, Alington, 48, High Southwick, Sunderland ... ... (E) Mar. 1892

K.

Keen, Harry Bernard, 6, Beauclere Terrace, Sunderland ... ... (S) Dec. 1889
Kennedy, Robert Sinclair, Foyle Street, Sunderland ... ... (E) April 1893
Kerr, William, 12, Croft Terrace, Jarrow-on-Tyne ... ... (S) Oct. 1891
King, John, 85, Park Road, Newcastle-on-Tyne ... ... (S) Dec. 1890
Kitchin, Arnold, 1, York Place, East Hartlepool ... ... (E) Dec. 1892

L.

Lewis, Ernest Edward, 68, Crown Street, Elswick Road, Newcastle-on-Tyne ... ... (S) Mar. 1890
Liebert, Richard A. E. ... ... (E) Dec. 1888
Ligertwood, Edmund ... ... (E) Nov. 1892
Lishman, John James, 16, Lovaine Place, North Shields ... ... (E) Dec. 1892
Lloyd, V. Evan, 1, Bank Terrace, Wallsend-on-Tyne ... ... (E) Oct. 1891
Lowry, Richard, 16, Milton Street, Shieldfield, Newcastle-on-Tyne (E) Nov. 1891
Lynn, John Robert Dent, 31, General Gordon Terrace, Sunderland (E) April 1893

M.

	ELECTED.
Marshall, John Richardson, 217, Jefferson Street, Newcastle-on-Tyne...	(E) Dec. 1892
Maslen, Frank E., The Rectory, Wallsend-on-Tyne	(E) Nov. 1891
Mather, Clifford B., 2, Eslington Road, Newcastle-on-Tyne ...	(S) Oct. 1892
McKenna, Francis, 46, Hodgson Street, Willington Quay-on-Tyne	(E) Dec. 1890
McRobie, Frank, 25, Victoria Street, Newcastle-on-Tyne	(E) Mar. 1889
Metcalf, Thos., Jun., 18, John Street, Sunderland	(S) May 1885
Moffatt, James, 7, Murray's Terrace, Belfast, Ireland	(E) Dec. 1889
Moroney, Edward F., 33, Tyne Road, Gateshead-on-Tyne	(E) Feb. 1892
Morton, John, 29, Azalea Terrace North, Sunderland	(E) Dec. 1892
Mould, Francis, 36, Salter's Road, Gosforth, Newcastle-on-Tyne ...	(E) Feb. 1892
Munro, Alexander, 29, Linskill Terrace, North Shields	(S) Oct. 1891
Murray, George Harper, 22, Bolingbroke Street, Heaton, Newcastle-on-Tyne	(S) Dec. 1892
Musgrave, Evers, c/o Messrs. T. Richardson & Sons, Hartlepool ...	(E) Nov. 1891

N.

Nichol, Bryce Gray, Jun., 49, Leazes Terrace, Newcastle-on-Tyne	(E) Oct. 1891
Nicholson, James Henry, 30, Azalea Terrace South, Sunderland ...	(E) Mar. 1892

O.

Orr, Reginald, 18, Bulwer Street, Shepherd's Bush, London, W. ...	(E) Mar. 1890
Oxton, Walter, 126, Church Street, Walker-on-Tyne, R.S.O. ...	(E) Dec. 1890

P.

Pattison, Matthew Robson, 14, Lambton Street, Sunderland ...	(E) Mar. 1891
Pettit, Arthur Edward, 1, South Crescent, East Hartlepool ...	(E) Dec. 1892
Phillips, John Frederick, 33, Tower Wall, East Hartlepool ...	(E) Oct. 1892
Pringle, Alfred, 10, Somerset Terrace, Walker-on-Tyne, R.S.O. ...	(S) Dec. 1891

R.

Reed, Joseph, Springfield, Forest Hall	(E) Feb. 1888
Reid, John Robert, 25, Derwent Street, Sunderland	(E) Nov. 1892
Rickaby, Augustine, Bloomfield Engine Works, Monkwearmouth, Sunderland...	(E) Nov. 1885
Ritson, Stanley M., 18, St. Bede's Terrace, Sunderland	(E) Nov. 1887
Roberts, T. C., 23, Kelvin Grove, Princes Park, Liverpool ...	(E) Oct. 1886
Ross, Wm. Chisholm, c/o Messrs. Hawthorn, Leslie, & Co., St. Peter's-on-Tyne	(E) Dec. 1888
Rowntree, Stanley, 62, Neptune Road, Wallsend-on-Tyne ...	(S) Jan. 1891
Rutherford, J. T., 40, Wharncliffe Street, Newcastle-on-Tyne ...	(E) Jan. 1886

S.

Scott, Joseph, 30, Mosley Street, Newcastle-on-Tyne	(E) Dec. 1891
Shaw, Thomas, East Boldon, near Sunderland	(S) Dec. 1885
Shilstone, Victor G., 14, Wentworth Place, Newcastle-on-Tyne ...	(N A) Nov. 1891
Short, Thomas Smart, c/o Messrs. Short Brothers, Pallion, Sunderland...	(S Oct. 1892

ELECTED.

Smith, Launcelot Eustace, 22, St. Mary's Place, Newcastle-on-Tyne... ... ... (E) Oct. 1889
Smithson, Alfred Edward, 1, Dawson Square, Tynemouth ... (E) Jan. 1891
Spencer, Harry John, 3, Victoria Street, Newcastle-on-Tyne ... (E) Dec. 1892
Spours, William, 106, Addison Road, Heaton, Newcastle-on-Tyne (E) Nov. 1891
Stanger, Thomas W., 38, Addison Road, Heaton, Newcastle-on-Tyne (E) Jan. 1892
Stephens, Henry C. J., 4, Wilberforce Street, Wallsend-on-Tyne... (E) Oct. 1890
Summerson, Benjamin, Dene Crescent, Walker-on-Tyne, R.S.O. ... (E) Dec. 1892
Swan, Charles Sheriton, 29, Percy Gardens, Tynemouth ... ... (S) Nov. 1890

T.

Taylor, M., c/o Messrs. Barclay, Curle, & Co., Shipbuilders, Whiteinch, near Glasgow ... ... (S) Feb. 1889
Thompson, John, Jun., Post Office Chambers, Newcastle-on-Tyne (C E) Oct. 1892

W.

Wakeham, John F., 50, De Grey Street, Newcastle-on-Tyne ... (S) Mar. 1893
Watson, Arthur C., 7, Thornhill Terrace, Sunderland ... ... (S) Nov. 1891
Wedgewood, Josiah Clement, 6, The Grove, Greenwich ... ... (S) April 1891
Weightman, Thomas, 179, Portland Road, Newcastle-on-Tyne ... (S) Dec. 1892
Wheeler, Oswald, 6, Blackwellgate, Darlington ... ... (E) Oct. 1886
White, Ernest T., 16, Abbey Terrace, Gateshead-on-Tyne ... ... (E) May 1889
Wight, Henry Dewair ... ... (E E) Oct. 1891
Wilkin, Ernest Vivian, 22, Victoria Street, Newcastle-on-Tyne ... (E) Nov. 1892
Willcox, Reginald J. N., The Oaks West, Sunderland ... ... (E) Mar. 1892
Wood, John Scott, 6, Eslington Terrace, Newcastle-on-Tyne ... (S) Oct. 1891

THE NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

Constitution and Bye-Laws,

ADOPTED AT A GENERAL MEETING ON THE 4TH MARCH, 1885.

REVISED AT THE CLOSING BUSINESS MEETING HELD ON MAY 4TH, 1887.

RE-REVISED AT THE CLOSING BUSINESS MEETINGS HELD ON MAY 9TH, 1888, MAY 13TH, 1889, AND MAY 11TH, 1891.

CONSTITUTION.

Name.

I.—The NAME of the Association is "The North-East Coast Institution of Engineers and Shipbuilders."

Objects.

II.—The OBJECTS for which the Institution is established are :—The advancement of the science and practice of Engineering and Shipbuilding, and the interchange of ideas and information amongst its members, by means of meetings for the reading and discussion of papers relating thereto, and placing on record its transactions.

III.—The Institution shall consist of Honorary Members, Members, Associates, and Graduates.

Honorary Members.

IV.—HONORARY MEMBERS shall be such distinguished persons as the Council may elect.

Members.

V.—MEMBERS shall be Principals or Principal Managers engaged in Engineering or Shipbuilding; Civil, Military, or Mining Engineers, or Naval Architects; whose subscription shall be Two Guineas per annum: and other persons engaged in the above professions; whose subscription shall be One Guinea per annum.

Associates.

VI.—ASSOCIATES shall be such persons as are not strictly Engineers or Shipbuilders, but are connected with or interested in such pursuits, and are deemed by the Council to be eligible for Associate membership. Their subscription shall be One Guinea per annum.

VII.—GRADUATES may be persons under twenty-four years of age, engaged in study or employment to qualify themselves for any of the above professions. Their subscription shall be Half-a-Guinea per annum. Graduates.

VIII.—Any MEMBER may become a LIFE MEMBER by a single payment of Twenty Guineas, or any ASSOCIATE may become a LIFE ASSOCIATE by a single payment of Ten Guineas. Life Members and Associates.

IX.—The OFFICERS of the Institution shall be elected from and by the Members, and shall consist of one President, the Past-Presidents, nine Vice-Presidents, fifteen Councilmen, and an Honorary Treasurer. Officers.

X.—The President and Honorary Treasurer shall be elected annually. Three Vice-Presidents and five Councilmen shall be elected annually. The retiring Vice-Presidents and Councilmen shall be those who have served three years from their last election. Election of Officers. (See Bye-Law No. 11.)

The President shall be eligible for re-election for a second year; should he be re-elected he shall retire at the conclusion of his second year of office, and shall not again be eligible until after an interval of one year.

The retiring Vice-Presidents shall be eligible for re-election. The retiring Councilmen shall not be eligible for re-election to the same office until after an interval of one year, but shall be eligible for election to any other office.

The Honorary Treasurer shall be eligible for re-election annually, or for election to any other office.

XI.—Honorary Members may attend all the General Meetings, they may read papers, take part in discussions, in voting, in moving and supporting resolutions, in presentation of notices of motion, or in requisitions for Special Meetings, and in the proposition of new members; they shall also receive copies of the Transactions. Honorary Members' Privileges.

XII.—Members shall have all the privileges of the Institution as enumerated in the foregoing paragraph, and shall be eligible for office. Members' Privileges.

XIII.—Associates shall have all the privileges enumerated in paragraph XI. They shall be eligible for office as Councilmen. Associates' Privileges.

XIV.—Graduates may attend all the General Meetings, they may read papers, take part in discussions, and support resolu- Graduates' Privileges.

tions; they shall also receive copies of the Transactions, but shall not sign proposals for new members, vote, nor be eligible for office.

General Meetings.

XV.—The General Meetings of the Institution shall be held during the winter seasons of each year.

NOTE.—When the word Member is initialled with a capital letter it signifies a member under paragraphs IV. and V., but when initialled with a small letter, it signifies a member of any class of the Institution membership.

BYE-LAWS.

Revised at the Closing Business Meetings held on May 4th, 1887, *May 13th,* 1889, *and May 11th,* 1891.

MEMBERSHIP.

Candidates for Admission.

1.—Every candidate for admission as a Member, Associate, or Graduate shall be proposed and recommended according to the Form A in the Appendix, in which form the name, usual residence or the place of business, the qualification for, and proposed class of membership of the candidate shall be distinctly specified. Proposals for Graduates must give the date of, and age, last birthday.

The form shall be signed by a Member or Associate of the Institution, as proposer, and by at least other three Members or Associates as supporters, certifying a personal knowledge of the candidate.

The proposal so made shall be submitted to the Council, when, if it be approved, the Chairman shall sign the approbation, which shall be inserted in the notice calling the next General Meeting, when the candidate shall be balloted for, and shall be accepted if three-fourths of the votes are favourable.

Graduates becoming Members.

2.—Graduates desirous of becoming Members shall be proposed and recommended according to the Form B in the Appendix.

The proposal so made shall be submitted to the Council, who shall agree to or reject it.

Balloting for Members.

3.—The balloting for membership shall be conducted in the following manner:—Each member shall be supplied by post with a list of the names of the candidates, according to the Form C in the Appendix, and shall strike out the names of such candidates as he desires shall not be elected. These lists may be

returned to the Secretary by post, or may be deposited in the ballot-box by the voter in person on entering a meeting at which an election is to take place. The ballot-box will be closed at ten minutes after the advertised time of meeting. The lists shall then be handed over to the Chairman, who shall appoint two Scrutineers to examine them, after which examination the Chairman shall inform the meeting of the result.

Candidates to receive Notice of Election.

4.—Notice of Election as a member shall be sent to the candidate within one week after his election, according to the Form D in the Appendix; but his name shall not be added to the list of Members, Associates, or Graduates of the Institution, until he shall have paid his first annual subscription.

Rejection of Candidates.

5.—In case of rejection of the candidate, no mention thereof shall be made in the minutes, nor shall any notice be given to the unsuccessful candidate.

Subscriptions payable in Advance.

6.—All subscriptions shall be payable in advance, and shall become due on the 1st of June each year. Any Member, Associate, or Graduate, wishing to retire from the Institution shall continue to be liable for his annual subscription until he shall have given formal notice of his retirement to the Secretary, which notice must be given on or before the 31st of August in each year. Application for membership may be made at any time during a Session, and the subscription shall cover the membership up to the 1st of June following.

Receipt of Subscription.

7.—On payment of each subscription the Secretary shall forward to the member an official receipt.

Questions of Privilege.

8.—On question of privilege.—Any person who may be unknown in the meeting shall only be able to claim the privilege in question on proving his membership for the current Session.

Arrears of Subscriptions.

9.—Any member whose subscription is one year in arrear shall be reported to the Council, who shall direct application to be made for it, according to Form E in the Appendix; and in the event of its continuing in arrear until the end of that Session after such application, the Council shall have the power, after remonstrance by letter, according to the Form F in the Appendix, of declaring that the defaulter has ceased to be a member.

Power of Council to remove Name from List of members.

10.—The Council may refuse to continue to receive the subscriptions of any member who shall have wittingly acted in contravention of the Regulations of the Institution, or who shall,

in the opinion of the Council, have been guilty of such conduct as shall have rendered him unfit to continue his membership; and the Council may remove his name from the list of members: and such person shall thereupon cease to be a member of the Institution. Notice of such action of the Council shall be forwarded to the person in question, in accordance with the Form G in the Appendix. The reason for such action of the Council shall not be stated to the person expelled, without the sanction of the Council.

OFFICERS.

Election of Officers.

11.—The Annual Election of Officers shall be conducted in the following manner:—The Council shall meet in March or April, and shall arrange a list of nominations, in accordance with the Form H in the Appendix. Such list shall be presented at the General Meeting immediately preceding the last General Meeting of the Session, and any Member present shall be at liberty to nominate additional Members. The list shall show who remain in office throughout the Council, and who are retiring. It shall nominate new names in the place of the retiring Members, and the number of nominations shall be one in excess of the number required in each section of the Council. A copy of this ballot list shall be forwarded to each Member and Associate, together with a complete list of Members, to be filled in, in accordance with the instructions printed in the ballot form, and to be returned to the Secretary, to be opened in the presence of the Council, at a Council Meeting which shall be held in April or May, when the scrutiny and counting shall be carried out by the Council. Any Member in voting shall be at liberty to erase any name or names from the list and substitute the names of any other person or persons eligible for each respective office other than those already placed on the ballot list by the Council and Members of the Institution.

Any voting paper returning either more or less than one President, six Vice-Presidents, one Honorary Treasurer, and fifteen Councilmen, shall be disqualified for the section or sections in which such errors occur, and the votes shall be lost for the said section or sections. The votes given as President, to a Member who is not elected President, shall count to him as a Vice-President; the votes given as Vice-President, or Treasurer,

to persons not so elected, shall count to them as Councilmen, unless they have just completed a term of office in such capacity.

The voting list shall not be sent to any Member and Associate whose subscriptions are more than one year in arrear; nor shall any Member be nominated on the list. For this purpose, the Secretary shall prepare, previously to the meeting of Council, a list of those Members whose subscriptions are more than one year in arrears.

Ballot to be declared at May Meeting.

12.—The result of the ballot for Officers shall be declared at the General Meeting, to be held in May, at which meeting general business shall be transacted. At the May General Meeting the newly-elected Officers, after being declared, shall enter into office; and this shall be the last meeting of the Session.

Power of Council to fill up Casual Vacancy.

13.—The Council shall have power to supply any casual vacancy within itself (including any casual vacancy in the office of President), which shall occur between one May Meeting and another; and the Officers so appointed shall retire when the person whose place they fill would have retired. Vacancies not filled up during the year shall be filled at the General Election.

GENERAL MEETINGS.

General Meetings.

14.—The Annual General Meeting shall take place in October, and shall be held in Newcastle. The Ordinary Meetings shall take place in the second week in each following month during the Session, unless otherwise arranged by the Council, and at such hours and places as the Council may determine.

Notice of Meetings.

15.—Seven clear days' notice of every General Meeting, Ordinary or Special, specifying the nature of business to be transacted, shall be given to every member of the Institution.

Special General Meetings.

16.—A Special General Meeting may be convened at any time by the Council, and such meeting shall be convened by the Council whenever such is the declared wish of a General Meeting, or whenever a written requisition, signed by twenty members, specifying the object of the meeting, is left with the Secretary. If, for fourteen days after the delivery of such requisition, a meeting be not convened in accordance therewith, the requisitionists, or any twenty members of the Institution, may convene a Special Meeting in accordance with the requisition. The business discussed at such Special Meetings shall only be that indicated on the notice calling the meeting.

Quorum.

17.—Twenty Members shall constitute a quorum for the purpose of a meeting other than a Special Meeting. Thirty Members shall constitute a quorum for the purpose of a Special Meeting.

Chairman at Meetings.

18.—The President shall be chairman at every meeting, and in his absence, one of the Past-Presidents or one of the Vice-Presidents; or in the absence of these, a Councilman shall take the chair; or if no Councilman be present and willing to take the chair, the meeting shall elect a Chairman.

Decisions of General Meetings.

19.—The decision of a General Meeting shall be ascertained by a show of hands; or, when five Members or Associates shall demand, or the Chairman may think it desirable, the decision shall be taken by ballot. The manner of counting the votes shall be at the discretion of the Chairman, and an entry in the minutes, signed by the Chairman, shall be deemed sufficient evidence of the decision of a General Meeting. In cases of equality of votes, the Chairman shall have a casting vote; otherwise he shall not vote.

Questions of a Personal Nature in General Meetings.

20.—Questions of a personal nature arising in a General Meeting, shall, if possible, be referred to the Council, otherwise the decision of the meeting shall be taken by ballot on a motion or amendment put to the meeting. The ballot shall be taken by the voters (being Members or Associates) writing "for" and "against" on a slip of paper. The slips shall be folded and collected, and then counted in the presence of the meeting, and the result announced by the Chairman. Should fewer than twenty votes be given, it shall be understood that the question is shelved, and the votes shall be destroyed without being opened.

Transactions of Business General Meetings.

21.—At every General Meeting of the Institution, the Secretary shall first read the minutes of the preceding meeting, which, on approval, shall be signed by the Chairman; business arising out of these minutes shall then be transacted. The Secretary shall read any notices which may have to be brought before the meeting. Notices of motion may then be given, and other business of the Institution may be attended to; but when a paper is to be read, the foregoing business shall not be extended beyond half-an-hour after the advertised time for commencing the meeting. The paper or papers for the evening shall then be read and discussed.

Dissolving a General Meeting.

22.—If within half-an-hour after the time fixed for holding a General Meeting a quorum is not present, the meeting shall be

dissolved, and all matters which might, if a quorum had been present, have been done at the meeting so dissolved, may forthwith be done on behalf of the meeting, by the Council; except the reading or discussion of a paper, which shall not proceed in the absence of a quorum.

23.—Any General Meeting of the Institution may be adjourned by a vote of the Members and Associates present if there be a quorum; if there be not a quorum, the case shall be met by the preceding paragraph. **Adjourning a General Meeting.**

24.—Each member shall have the privilege of introducing one friend to the General Meetings, whose name must be written in the Visitors' Book, together with that of the member introducing him; but if the introducing member be unable to attend the meeting, he may send the name of the visitor to the Secretary. During such portions of any of these meetings as may be devoted to any business connected with the management of the Institution, visitors may be requested by the Chairman to withdraw. This shall be done if five Members or Associates, or both, present request it. **Introduction of Friends.**

COUNCIL MEETINGS.

25.—The Council shall meet before each General Meeting, or on other occasions when the President shall deem it necessary; being summoned in either case by circular, stating the time of meeting, and the business, so far as is known. **Council Meetings.**

No business involving expenditure of the funds of the Institution (except by way of payment of current accounts) shall be transacted at any Council Meeting, unless the circular gives six clear days' notice, and states the business. **Convening Meeting for Expenditure of Funds.**

All discussions of a personal character in the Council shall be considered and treated as being strictly confidential. **Discussions of Personal Character.**

26.—The Council may regulate its own procedure, and delegate any of its powers and discretions to any one or more of its number. **Regulation of Proceedings.**

The President shall, *ex-officio*, be chairman of all Council Meetings, and in his absence one of the Past-Presidents or one of the Vice-Presidents shall take the chair; or in the absence of these, one of the Councilmen shall be elected to take the chair. Five members of Council, including the Chairman, shall form a quorum. **Chairman and Quorum.**

In the appointment of Sub-Committees, the Council shall determine the number which shall form a quorum in each case, **Sub-Committees.**

and shall appoint a Chairman. These regulations shall not affect the Finance Committee.

Sub-Committees.

27.—The Council may appoint Committees either from itself, or with the assistance of persons outside, for the purpose of transacting any special business, or of investigating specific objects connected with the work and interests of the Institution.

Sub-Committees.

28.—All Committees or Sub-Committees shall be appointed by the Council, and shall be subject to that body, and shall report to it. The Council shall act upon these reports or recommendations as it may think best.

Invitation to Strangers.

29.—The Council may invite to General Meetings or to Council Meetings any person or persons whose presence and assistance it may desire, and strangers so invited shall be permitted to take part in the proceedings, but not to vote.

Secretary and Treasurer's Duties.

30.—The Secretary, who shall also act as Treasurer, shall be appointed by and act under the direction and control of the Council, and shall be paid such salary as the Council shall determine. He shall attend all meetings, Council and General, and shall take minutes of the proceedings, and enter them in proper books provided for the purpose. He shall write the correspondence of the Institution and Council, read minutes and notices at meetings, report discussions, and, if required by the Council, prepare papers for reading and publication, and read papers and communications at the meetings. He shall receive all payments due to the Institution, and shall bank the cash in hand whenever it amounts to ten pounds. The bank shall be determined by the Council and the banking account shall be in the names indicated in connection with the Finance Committee. He shall keep a cash account book, general and detail, which shall on all occasions be open to inspection by the Finance Committee or by the Council. He shall keep a register of the names of members, so arranged as to distinguish all members whose subscriptions are in arrear. He shall also perform whatever other duties are indicated in the Bye-Laws of the Institution as appertaining to his department; and shall remain in office during the pleasure of the Council. He shall not vote on any resolution.

31.—The following Sub-Committees shall be appointed annually at the first meeting of the Council in each Session:—

Finance Committee.

(1) A Finance Committee, to consist of seven persons, viz.: one Past-President or Vice-President, who shall be Chairman; five

Councilmen, and the Honorary Treasurer of the Institution; three of whom shall form a quorum. The Treasurer shall be empowered to pay all amounts due from the Institution which are under two pounds. All amounts of two pounds and upwards shall be paid by cheque, signed by the Chairman of the Finance Committee (or in his absence, by the President or a Past-President), the Secretary and the Honorary Treasurer. (2) A Reading Committee, to consist of six members of Council. No member who has served on this Committee for three years in succession shall be eligible for re-election until after an interval of one year. (3) A Library Committee, in accordance with Library Bye-Laws, Nos. 1 and 3.

Payment of Accounts.

Reading and Library Committees.

TRANSACTIONS.

32.—All papers shall be forwarded to the Secretary at least five clear weeks before the proposed date of reading. The Secretary shall submit them for approval to the Council, and on their general approval they shall be handed to the Reading Sub-Committee, three of whom at least, shall read the paper through. The Reading Committee shall be at liberty to strike out any parts which, in their opinion, ought not to be read. They may also make any suggestions to the author as to points which might with advantage be inserted or altered.

Papers to be submitted to Council.

Reading Committee.

33.—The papers read, and the discussions on them, or such portions of them as the Council shall select, shall be printed for distribution among the members, each of whom shall receive a copy. These Transactions shall be edited by the Secretary, in accordance with instructions of the Council, who shall have power to omit parts of discussion which may be foreign to the subject, or which it may be deemed undesirable to retain. Each paper shall bear the date on which it was read in General Meeting.

Printing Transactions.

34.—Copies of papers to be read during any Session will be sent seven days before the date of reading to members who shall have applied to the Secretary for them, in writing, at the commencement of the Session. The discussion on a paper shall not be considered closed on the evening on which it is read, but shall be open for renewal at a subsequent meeting, prior to the reading of the paper set down for that date.

Copy of Papers supplied to members before reading, etc.

35.—The Secretary shall send to each speaker as soon as possible after a General Meeting a copy in manuscript of the speaker's own remarks for correction. This copy must be re-

Proofs sent to members for Correction.

turned to the Secretary within four days. A printed proof will also be sent to each speaker for further revision; this must be returned to the Secretary within three days, otherwise it will be deemed correct, and printed off after receiving verbal corrections.

Liberty to Print Explanatory Notes.

36.—The Council shall be at liberty to print as Transactions, either with the papers and discussions or separately, explanatory notes, etc., communicated after the reading or discussing of a paper. Such communications must be approved by the Reading Committee, and shall bear the date on which they shall have been received by the Secretary.

Institution not responsible for statements.

37.—The Institution shall not be held responsible for the statements and opinions advanced in any of the papers which may be read, or in the discussions which may take place at the Meetings of the Institution.

Copies of Transactions to be sent to members.

38.—Twenty copies of each paper and discussion shall be presented to the author of the paper, for private use, and one copy shall be sent to each member. When a paper is prepared by two authors, fifteen copies shall be presented to each. Duplicate copies of parts of the Transactions mislaid or lost by members cannot be supplied to them, except as provided for in Bye-Law 41.

Transactions not supplied to members in Arrears.

39.—The Transactions shall not be supplied free to members whose subscriptions are more than one year in arrear.

Members not to receive Transactions till after First Payment.

40.—Any member elected at any time between the Annual General Meetings shall be entitled to copies of all the Transactions issued during the Session to which his first subscription applies; but not until the subscription has been paid.

Transactions the Property of the Institution.

41.—The Transactions of the Institution shall be the exclusive property of the Institution, and shall be published only by the authority of the Council. Additional copies of papers required by authors for their private use can only be procured from the Secretary, at prices fixed by the Council from time to time, and these copies must contain the whole of the discussion following the papers, and be bound in the usual cover, with the addition of the following words:—"By permission of the Council," and "Excerpt Minutes of Proceedings." Duplicate volumes and copies of parts of the Transactions, if in print, can also be obtained from the Secretary, and shall be sold only by him, in such manner and at such prices as the Council shall have fixed.

42.—During a discussion upon any paper, no person shall be at liberty to speak more than once (except by way of explanation), nor for a longer period than ten minutes. Rule of Discussion.

ACCOUNTS, &c.

43.—The Council shall present the yearly accounts (up to the 31st of May preceding) at the October General Meeting of each year, after they have been audited by a professional Accountant, appointed by the members at the General Meeting in May. Accounts.

44.—The capital, stock, and funds of this Institution shall be vested in the names of three Trustees, to be elected from time to time as vacancies occur by the members of the Institution at a General Meeting called for that purpose. All mortgages and other securities shall be taken in the names of such Trustees; and on any new appointment the funds shall vest in the newly-appointed Trustee or Trustees jointly with the continuing or remaining Trustee or Trustees. Trustees.

ALTERATIONS TO CONSTITUTION AND BYE-LAWS.

45.—Alteration in or addition to the Constitution and Bye-Laws may be made only by resolution of the members at the May General Meeting, after notice of the proposed alteration or addition has been announced at the previous General Meeting.

The resolution may be modified by the Council meanwhile, should they so desire; but in this case it shall be read at the May General Meeting in its original form before it is proposed in the amended form.

Such resolutions shall be stated in the notice calling the intervening Council Meeting, and also in the notice calling the May General Meeting.

Any member unable to be present at the meeting at which such alterations are to be considered, but who is nevertheless desirous of recording his opinion thereon, shall be allowed to vote by proxy, such proxies shall be in Form J in the Appendix, which may be had on application to the Secretary, and may be used by any member present at the meeting on behalf of the absent member, and counted by the Chairman as of equal value with votes given in the manner provided in Bye-Law 19. Vote by Proxy.

THE LIBRARY AND READING ROOM BYE-LAWS.

Committee.

1.—The Library and Reading Room shall be managed by a Committee, called the Library Committee, who shall have charge of all books, papers, specimens, etc., which may belong to the Institution. It shall consist of five members of the Institution, of whom at least two shall be members of Council.

Property.

2.—The books and other property of the Library shall be vested in the Trustees appointed by the Institution.

Appointment of Committee.

3.—The Library Committee shall be appointed annually, at the first meeting of the Council in each Session. No member who has served on the Committee for three years in succession shall be eligible for re-election until after an interval of one year. The Chairman shall be elected by the Council.

Librarian.

4.—The Secretary of the Institution shall be Librarian, and shall also act as Secretary to the Library Committee. Three members of the Committee shall form a quorum.

Duties of Committee.

5.—The Library Committee shall be responsible for the binding and purchasing of books, periodicals, papers, etc., and for the expending of all money voted by the Council for its use. It shall appoint an attendant who shall act as Assistant Librarian. It shall make Bye-Laws for the management of the Library, subject to the approval of the Council, and present an annual report to the first meeting of the Council held after the annual scrutiny of the books referred to in Bye-Law No. 13.

Hours of Opening and Closing, &c.

6.—Except when closed by special order of the Library Committee, or when the Council is sitting, the Library and Reading Room shall be open for consulting, borrowing, or returning books, every week day as follows:—On Monday, Tuesday, Wednesday, and Friday, from 10 a.m. to 12 noon, and from 1 to 9 p.m.; on Thursday, from 10 a.m. to 12 noon, and from 1 to 5 p.m.; on Saturday, from 10 a.m. to 1 p.m., and from 2·30 to 9 p.m. The Rooms will be closed on Christmas Day and the day following, New Year's Day and the day following, Good Friday, Monday and Tuesday in Easter week and Whit week; and at noon on Tuesday, Wednesday, Thursday and Friday in the Race week of June, and the first Monday in August (being Bank Holiday); also from the first to the second Saturday in March of each year, as mentioned in Bye-Law No. 13.

Lending of Books.

7.—Books shall not be lent to any persons except Members, Associates, or Graduates of the Institution, but a person entitled to borrow a book may send a messenger with a signed order for it.

8.—Each member shall be entitled to introduce a friend to the Reading Room, whose name shall be written in the Visitors' Book, together with that of the member introducing him. **Visitors.**

9.—The books marked with an asterisk in the Catalogue shall be kept only for consultation in the Library, and shall not be lent. Pending the preparation of a Catalogue, the Librarian shall be instructed by the Committee as to which books shall be withheld from circulation. **Reference Books.**

No periodicals, magazines, or pamphlets shall be issued for circulation until after they have been bound and added to the Lending Library. **Unbound Books.**

10.—The Librarian shall keep a register in which he himself or the attendant shall enter the titles of the books lent, the date of lending, the name of the borrower, and the date of the return of the book to the Library. The borrower of the book or the bearer of his order shall initial the entry of such borrowing, and the Librarian or the attendant shall initial the date of the return of the book. **Register of Books Lent, etc.**

11.—No person shall borrow or have in his possession at one time more than two volumes belonging to the Library. **Number Lent to each member.**

12.—No member shall retain a book longer than fourteen days, excluding the day of issue. He shall be responsible for the safe return of the book, and if it be damaged or lost he shall make good the cost of such damage or loss. **Return of Books.**

13.—All books belonging to the Library shall be called in for inspection, and the lending out of books shall be suspended from the first to the second Saturday of March, inclusive, of each year, and members shall be required by an intimation inserted in the notice calling the preceding meeting of the Institution to return all books in their hands before the period mentioned. **Yearly Inspection of Books.**

Members failing to comply with this injunction shall pay a fine of two shillings and sixpence. **Fine.**

14.—Members are requested, when in the Reading Room or Library, to contribute to the general comfort by carefully abstaining from loud talking and noise of any kind. Smoking is not permitted in the Library.

15.—Any member being twelve months in arrears with his subscriptions to the Institution shall not be at liberty to use the Library or Reading Room after the commencement of the first Session following. **Members in Arrears.**

N.B.—The foregoing Rules may be amended at any time by the Library Committee with the sanction of the Council.

APPENDIX TO BYE-LAWS.

FORM A. (BYE-LAW 1.)

Name (in full)
Profession or Occupation and where Employed
Address
being desirous of admission into the North-East Coast Institution of Engineers and Shipbuilders, we, the undersigned, propose and recommend that he shall become*
thereof. We know him to be†
and eligible for the proposed membership.

* A Member, Associate, or Graduate.

† A Principal, Manager, or Draughtsman, etc. See Articles V., VI., and VII of Constitution.

	FROM PERSONAL KNOWLEDGE.	SECTION OF MEMBERSHIP.
Proposed by		
Supported by Three Members or Associates.		

Dated this day of

(*When a Graduate is proposed the age last birthday should be stated.*)

FORM B. (BYE-LAW 2.)

A. B. [Christian Name, Surname, Occupation, and Address in full] being at present a of the North-East Coast Institution of Engineers and Shipbuilders, and upwards of twenty-four years of age, and being desirous of becoming a of the said Institute, we, the undersigned [Members or Associates], recommend him, from *personal knowledge*, as a person eligible for the proposed Change of membership, because—

(*Here specify distinctly the Qualifications of the Candidate according to the spirit of the Rules of the Institution.*)

Signed _____
_____ } Three [Members or Associates.]
_____

Dated this day of 18

FORM C. (BYE-LAW 3.)

BALLOTING PAPER FOR MEMBERSHIP.

The Council having considered the recommendations for Membership of the following gentlemen, present them to be balloted for, viz.:—

Member, Associate, or Graduate.	Occupation.	Address.	Nominated by.	Supported by Three Members or Associates.

Strike out the names of such persons as you desire shall *not* be elected, and forward the list by post to the Secretary, or personally place it in the ballot-box at the Meeting.

FORM D. (BYE-LAW 4.)

Sir,—I am directed to inform you that on the day of you were elected a of the North-East Coast Institution of Engineers and Shipbuilders, but, in conformity with Bye-Law 4, your election cannot be confirmed, nor your name be added to the roll of membership, until you have paid your first annual subscription, the amount of which is £ : : , or, at your option, the Life Composition of £ : : .

Payment may be made to the Treasurer, Mr. _____

Address _____

I am, Sir,

Yours faithfully,

Secretary.

Dated 18

N.B.—In case of a Graduate, strike out "*or, at your option, the Life Composition of £ : : .*"

FORM E. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to draw your attention to Bye-Law 6, and to remind you that the sum of £ of your annual subscriptions remains unpaid, and that you are in consequence in arrear of subscription.

I am also directed to request that you will cause the same to be paid without further delay, otherwise the Council will be under the necessity of exercising their discretion as to using the power vested in them by the Rule above referred to.

I am, Sir,

Yours faithfully,

Secretary.

FORM F. (BYE-LAW 9.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that in consequence of non-payment of your arrears of subscription, and in pursuance of Bye-Law 9, the Council have determined that unless payment of the amount (£) is made previous to the day of next, they will proceed to declare that you have ceased to be a member of the Institution.

But, notwithstanding this declaration, you will remain liable for payment of the arrears due from you.

I am, Sir,

Yours faithfully,

Secretary.

FORM G. (BYE-LAW 10.)

SIR,—I am directed by the Council of the North-East Coast Institution of Engineers and Shipbuilders to inform you that they feel it their duty to advise you to withdraw from the Institution, or otherwise they will be obliged to act in accordance with Bye-Law 9 (or 10, as the case may be.)

I am, Sir,

Yours faithfully,

Secretary.

FORM H. (BYE-LAW 11.)

BALLOTING LIST.

PRESIDENT.—ONE NAME only to be returned, or the vote will be lost.

——— President for the current year (eligible for re-election.)*

——— } New Nominations, from whom to select ONE.

VICE-PRESIDENTS.—NINE NAMES only to be returned (including the six who remain in office), or the vote will be lost.

——— } Six Vice-Presidents remaining in office, whose seats are NOT vacant.

——— } Three Vice-Presidents retiring, eligible for re-election.

——— } New Nominations, from whom to select THREE names.

TREASURER.—ONE NAME only to be returned, or the vote will be lost.

——— Treasurer for the current year, eligible for re-election.

——— } New Nominations, from whom to select ONE.

COUNCILMEN.—FIFTEEN NAMES only to be returned, including the ten who remain in office.

——— } Ten Councilmen remaining in office. These do not require to be voted for at this election, as their term of service has NOT yet expired.

——— } Five Councilmen retiring, and NOT eligible for re-election.

——— } New Nominations, from whom to select FIVE.

* To be crossed out before issue, when the President is not eligible for re-election.

N.B.—(*a*) The names of those who remain in office will be counted in the total number required without being re-written by the voter.

(*b*) Any list having either MORE or LESS than the required number of names voted for in any section will be disqualified for that section.

(*c*) Votes as President for a person who is not elected will count for him as a Vice-President.

(*d*) Votes as Vice-President, or Treasurer, for persons not so elected, will count for them as Councilmen, unless they have just completed a term of office in that capacity.

(*e*) This list, duly filled in, may be returned to the Secretary by post, or handed to him, so as to be on the Council table before the commencement of the scrutiny, which is appointed to take place in the Council Room, at 8 p.m., on 18

(*f*) A copy of this list shall be posted at least Seven Days previous to the Annual Meeting to every Member and Associate, who may erase any name or names from the list and substitute the name or names of any other person or persons eligible for such respective offices, but the number of persons on the list after such erasure or substitution must not exceed the number to be elected to the respective offices.

Secretary.

FORM J. (BYE-LAW 45.)

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

FORM OF PROXY.

FOR VOTES ON ALTERATIONS TO CONSTITUTION OR BYE-LAWS.

I,....., being [an Honorary Member, Member, or Associate] of the above Institution, do hereby appoint Mr..... who is [an Honorary Member, Member, or Associate] of the same Institution, to act as my Proxy, and record my Vote at the General Meeting of the Institution, to be held on the... .....day of ....., 18....., and at any adjournment thereof.

Signature.....

Address.....

.....

.....*Secretary*.

NORTH-EAST COAST INSTITUTION

OF

ENGINEERS AND SHIPBUILDERS.

NINTH SESSION, 1892–93.

PROCEEDINGS.

NINTH ANNUAL GENERAL MEETING, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON MONDAY EVENING, 10TH OCTOBER, 1892.

ROBERT THOMPSON, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the preceding General Meeting (Closing Meeting of last session), held on May 9th, 1892, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Mr. Alex. Taylor and Mr. John Gravell to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Angus, W. J., Engine Draughtsman, c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness.

Baird, George, Engine Draughtsman, 22, Lovaine Place, North Shields.

Bull, John Carl, Engineer, 18, Bexley Road, Erith, Kent.

Cameron, Henry, Engineer, Hazlebank, Trinity, Edinburgh.

Chicken, Thomas, Engineer, c/o Messrs. Newport Engineering and Ship Repairing Co., Newport, Mon.

Copeman, William C. J., Supt. Engineer, 10, Brinkburn Terrace, South Shields.

Donkin, George, Engineer, St. Andrew's Engine Works, Newcastle-on-Tyne.

Duguid, Robert, Ship Draughtsman, 108, Byker Street, Walker-on-Tyne.

Dyer, Charles M. B., Engine Surveyor, c/o Lloyd's Register of Shipping, 3, St. Nicholas' Buildings, Newcastle-on-Tyne.

Fenwick, James, B.Sc., C.E., Engineer, Belmore House, Belmore, near Sydney, New South Wales.

Inman, Douglas, S., Engine Draughtsman, 17, Wandsworth Road, Heaton, Newcastle-on-Tyne.

Kerfoot, James, Supt. Engineer, 7, Queen's Terrace, Jesmond, Newcastle-on-Tyne.

Laing, Andrew, Engineer, Fairfield Works, Govan, Glasgow.

Middleton, Robert Alex., Naval Architect, Fairfield Works, Govan, Glasgow.

Muir, Robert Home, Shipbuilder, 24, Lovaine Place, Newcastle-on-Tyne.

Noble, J., Supt. Engineer, 48, Marine Approach, South Shields.

Oliver, Hedley, Consulting Engineer, 6, Tower Chambers, Water Street, Liverpool.

Peacock, Nicholas B. J., Supt. Engineer, 30, Dingle Road, Tranmere Park, Birkenhead.

Pringle, James G., Ship Draughtsman, 10, Somerset Terrace, Walker-on-Tyne.

Purdon, Andrew S., Ship Draughtsman, Fairfield Works, Govan, Glasgow.

Ramage, John Anderson, Ship Draughtsman, 74, Park Terrace, Hebburn-on-Tyne.

Richards, George B., Engineer, c/o Messrs. Westray, Copeland, & Co., Barrow-in-Furness.

Scott, James, Engineer, c/o Messrs. Consett Iron Co., Blackhill, Co. Durham.

Syme, James, Engineer, Fairfield Works, Govan, Glasgow.

Thompson, John Augustus, Consulting Engineer and Naval Architect, 12, London Street, Fenchurch Street, London, E.C.

Trail, John, Marine Engineering Superintendent, c/o James Knott, Esq., Quayside, Newcastle-on-Tyne.

Whittaker, Frederick W., Engineer, c/o Messrs. Naval Construction and Armaments Co., Barrow-in-Furness.

MEMBERS (LATE GRADUATES).

Elder, Edward, Ship Draughtsman, London House, Jarrow-on-Tyne.

Foley, W. C. le B., Shipbuilder, 12, Grove Street, Newcastle-on-Tyne.

King, John, Ship Draughtsman, 85, Park Road, Newcastle-on-Tyne.

Lewis, Ernest Edward, Ship Draughtsman, 68, Crown Street, Elswick Road, Newcastle-on-Tyne.

Moffatt, James, Engine Draughtsman, 7, Murray's Terrace, Belfast.

Orr, Reginald, Engineer, 18, Bulwer Street, Shepherd's Bush, London, W.

Smith, Launcelot Eustace, Engineer, 34, Lovaine Place, Newcastle-on-Tyne.

Wheeler, Oswald, Engineer, 22, Collingwood Street, Newcastle-on-Tyne.

ASSOCIATES.

Caws, Frank, Architect, 22, Fawcett Street, Sunderland.

Lockie, John, Shipowner, 4, Sanderson Road, West Jesmond, Newcastle-on-Tyne.

GRADUATES.

Armstrong, Wm. S., Ship Draughtsman, 63, Croft Terrace, Jarrow-on-Tyne.

Mather, Clifford B., Apprentice Shipbuilder, 2, Eslington Road, Newcastle-on-Tyne.

Phillips, John Frederick, Apprentice Engineer, 18, Gladstone Street, East Hartlepool.

Short, Thomas Smart, Apprentice Shipbuilder, c/o Messrs. Short Brothers, Pallion, Sunderland.

Taylor, John Robert, Apprentice Engineer, Hawthorn Road, Gosforth, Newcastle-on-Tyne.

Thompson, John, Jun., Civil Engineer, Post Office Chambers, Newcastle-on-Tyne.

EIGHTH ANNUAL REPORT AND FINANCIAL STATEMENT.

The following report of the Council was read by the SECRETARY, and the Financial Statement adjoining was taken as read :—

COUNCIL REPORT.

(EIGHTH SESSION.)

IN presenting the eighth annual report the Council has pleasure in stating that the financial position of the Institution is still satisfactory, but regrets to have to announce that there are a number of subscriptions still unpaid.

The session was opened by a conversazione given by the President, Mr. Wigham Richardson, at which Mr. R. L. Weighton, M.A., was introduced to the members and their friends in his new capacity of Professor of Engineering and Naval Architecture in the Durham College of Science.

During the session the following papers were read and discussed :—

1.—"Proposed Improvements in the Construction of the Bottoms of Ships and Steamers." By Mr. E. F. Wailes.
2.—"Pumping Arrangements, etc., for Steam Vessels." By Mr. J. F. Walliker.
3.—"Engines for Ships of War." By Mr. J. Jennings Campbell.
4.—"On Tonnage Measurement." By Mr. M. C. James.
5.—"The Careening of Ships and Steamers for the purpose of practically testing their Stability." By Mr. E. F. Wailes.
6.—"The Rapid Filtration of Feed-water." By Mr. J. B. Edmiston.
7.—"River Steamers for Indian Railways." By Mr. Seymour B. Tritton.
8.—"A Proposed New Type of Cargo Steamer." By Mr. G. Bergström.
9.—"On the Design and Fitting of Stern Tubes, Stern Bushes, and Propeller Shaft Liners." By Mr. R. Hirst.

A further improvement has taken place in the Graduates' section. The third session was opened by an instructive address delivered by the President of the section, Mr. Balfour Bramwell, dealing chiefly with the subject of the expansion of steam in steam engine cylinders. Seven meetings were held during the session, at which the following papers were read and discussed :—

1.—"Some Notes on the Propulsion of Paddle Steamers." By Mr. J. King.
2.—"On the Combustion of Coal." By Mr. O. Wheeler.
3.—"The Distribution of Electricity for Lighting Purposes." By Mr. J. Brentnall Duckitt.
4.—"Steamship Trials." By Mr. R. L. Gaine.
5.—"Hydraulics and Hydraulic Machinery." By Mr. E. Towers.

Much credit is due to the authors for the elaborate manner in which these papers were illustrated, chiefly by lantern slides, requiring much time and care in their preparation. The papers themselves were of no mean value.

During the year visits were paid by the Graduates to the following works:—

Messrs. Clarke, Chapman, & Co.'s Victoria Works, Gateshead-on-Tyne;
" Foster, Blackett, & Wilson's Lead Works, Hebburn-on-Tyne;
" John Dickinson's Engine Works, Sunderland;
" Palmer's Shipbuilding and Engine Works, Jarrow-on-Tyne;

and the thanks of the Institution are due to the proprietors of these establishments for their kindness in permitting these visits to be made; likewise to the officials for the trouble and care taken by them in explaining and elucidating the various processes of manufacture exhibited.

The Council expresses regret that these meetings and visits were not better attended; as it must be admitted that an average attendance of 18 at the meetings and 23 when a works was visited is a very small percentage out of a membership of 110 Graduates.

Mr. R. L. Gaine has been elected President of the section for the current year, and as there are already several papers promised the Council hopes that the Graduates will further avail themselves of the privileges granted to them, and thus endeavour to make this section of the Institution one of unparalleled success.

During the past year 118 new members have been enrolled, viz.:— 63 Ordinary Members, 13 Associates, and 42 Graduates. The Institution has lost by deaths, resignations, and other causes 34 Ordinary Members, 4 Associates, and 11 Graduates.

The Council deeply regrets the loss sustained by the Institution through the death of the late Mr. B. G. Nichol, who held the office of Hon. Treasurer of the Institution since its formation in 1884.

The attention of the members is specially called to the following resolution moved by Mr. G. W. Sivewright and passed by the Council:—

> That any member may by communication addressed to the Secretary petition the Council to lay before a general meeting of the Institution the contents of any letter which shall in a short, concise, and clear manner draw the attention of the Institution to public matters of importance in connection with legislation proposed by any governing body in reference to the construction of ships, machinery, or the working of the same, so that members may by their scientific and practical knowledge demonstrate the soundness or otherwise of the proposed measure. (See page 86, Vol. VIII. of Transactions.)

The thanks of the Institution are due to those firms and gentlemen who, in response to the appeal made by the Council, have kindly subscribed to the fund guaranteed by the Institution towards the salary of the Professor of Engineering and Shipbuilding in the Durham College of Science, a list of whom will be found appended to the Financial Statement.

The gold medals for the seventh session were awarded to Mr. A. Blechynden for his able paper on "Screw Propellers," and to Mr. W. Hök for his two papers on the "Unsinkability of Cargo Carrying Vessels." In the Graduate section the first prize was awarded to Mr. Balfour Bramwell for his paper on "The Strength of Materials." The second and third papers being of equal merit the second prize was divided between Mr. Ernest T. White for his paper on the "Willans Central Steam Valve Engine" and Mr. R. L. Gaine for his paper on the "History of the Development of the Screw Propeller."

Mr. William Boyd having found it necessary to resign his seats on the Council of the Durham College of Science and the Sub-Committee of the County of Northumberland Technical Education Committee, Mr. John Gravell was appointed to fill his place on the Council of the Durham College of Science, and Mr. Alexander Taylor on the Sub-Committee of the County of Northumberland Technical Education Committee.

In response to the kind invitation received from Messrs. John Brown & Co. the members of the Institution visited the Atlas Iron and Steel Works, Sheffield, on Friday, the 24th day of June last. They were warmly received and entertained by the chairman and officers of the company, the trip in every way being most successful and instructive.

NORTH-EAST COAST INSTITUTION OF

STATEMENT OF RECEIPTS AND PAYMENTS

Receipts.

		£ s. d.	£ s. d.
To Balance from last Account—			
At Bankers		421 12 2	
In hand		13 15 0	
			435 7 2
„ Subscriptions received for Session 1891-92—			
212 Members at £2 2s.	£445 4 0		
384 Members „ £1 1s.	403 4 0		
102 Associates „ £1 1s.	107 2 0		
100 Graduates „ 10s. 6d.	52 10 0		
798		1,008 0 0	
„ Arrears for Sessions 1887 to 1891—			
1 Member at £2 2s.	£2 2 0		
13 Members „ £1 1s.	13 13 0		
1 Associate „ £1 1s.	1 1 0		
		16 16 0	
			1,024 16 0
„ Transactions sold this Session		36 14 9	
„ Copies of Members' Papers supplied		40 19 6	
			77 14 3
„ Tyne Improvement Commissioners—			
One Year's Interest to 21st June, 1892, on £605, at 3½ per cent.		21 18 6	
Less—Tax		0 10 11	
			21 7 7
„ Chair of Engineering and Naval Architecture Fund—			
Donations			426 11 0
„ Balance from Sheffield Excursion			6 4 0
			£1,992 0 0

ENGINEERS AND SHIPBUILDERS.

FOR SESSION ENDING 31ST MAY, 1892.

Payments.

	£	s.	d.	£	s.	d.
By Transactions and Papers—						
Lithographing	166	1	0			
Printing and Binding	185	1	3			
				351	2	3
„ Stationery and Circulars	77	19	1			
„ Reporting	23	14	0			
„ Rents—						
Offices	65	4	0			
Lecture Rooms	9	18	0			
Telephone	8	0	0			
„ Rates, Gas, and Insurance	12	13	8			
„ Salaries—						
Secretary, Salary	220	0	0			
Do. Commission	51	4	9			
Assistant Librarian	25	0	0			
„ Postages, Stamps, Post Cards, Parcels, etc.	91	2	9			
„ Secretary's Expenses and Allowances to Hall Keepers ...	13	8	11			
„ Office Expenses, Coals, Cleaning, etc.	18	5	10			
„ Rent for Measured Mile Posts	3	3	0			
„ Auditor's Fee	3	3	0			
				622	17	0
„ Library Fund—						
Furniture	8	13	6			
New Books	24	5	4			
Bookbinding	5	6	9			
				38	5	7
„ Chair of Engineering and Naval Architecture Fund—						
One Year's donation towards Salary of Professor ...				230	0	0
„ Gold Medals' Fund (Two Medals and Dies)	12	0	0			
„ Graduates' Award Fund—Amounts Awarded for Papers...	7	12	6			
				19	12	6
„ Balance—						
At Bankers...	723	0	11			
In hand	7	1	9			
				730	2	8
				£1,992	0	0

THE BALANCE SHEET.—FOR THE SESSION ENDING 31ST MAY, 1892.

Liabilities.

		£ s. d.	£ s. d.
Capital			1,623 3 4
Chair of Engineering and Naval Architecture Fund—Donations received:—			
Session 1890–91	£27 2 0		
„ 1891–92	426 11 0		
		453 13 0	
Less Amount Paid to Durham College of Science		230 0 0	
			223 13 0
			£1,864 16 4

Assets.

		£ s. d.	£ s. d.
Subscriptions in Arrear—			
Session 1889–90		2 12 6	
„ 1890–91		14 14 0	
„ 1891–92		70 17 6	
			88 4 0
Transactions sold, not yet paid for			1 6 6
Stock of Transactions, valued at			132 17 10
Office and Library Furniture, Safe, etc., as at 31st May, 1891 ...	£128 16 0		
Less Depreciation	12 17 6		
		115 18 6	
Additions this Session		8 13 6	
			124 12 0
Books in Library—			
As at 31st May, 1891 ...	£150 1 3		
Less Depreciation ...	15 0 0		
		135 1 3	
Additions this Session		29 12 1	
			164 13 4
Tyne Improvement Commissioners—Investment of the following Funds:—			
Gold Medals' Fund		274 0 0	
Graduates' Award Fund		215 15 0	
Payments by Life Members and Associates		115 5 0	
			605 0 0
Cash—At Bankers		723 0 11	
In hand		7 1 9	
			730 2 8
			£1,846 16 4

Newcastle-upon-Tyne, 22nd September, 1892.

Audited and certified,
R. W. SISSON, F.C.A.

LIST OF SUBSCRIPTIONS

RECEIVED TOWARDS THE SALARY OF THE PROFESSOR OF ENGINEERING AND NAVAL ARCHITECTURE IN THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-ON-TYNE. AUGUST, 1892.

	£	s.	d.
Sir William Gray, West Hartlepool	30	0	0
Messrs. Palmer's Shipbuilding and Iron Company, Jarrow-on-Tyne	30	0	0
„ Wigham Richardson & Co., Walker-on-Tyne ...	30	0	0
„ John Readhead & Sons, South Shields	25	0	0
„ C. S. Swan & Hunter, Wallsend-on-Tyne ...	25	0	0
„ George Clark & Co., Sunderland	20	0	0
John Dickinson, Esq., Sunderland	20	0	0
Messrs. W. Doxford & Sons, Sunderland	20	0	0
James Laing, Esq., Sunderland	20	0	0
Charles Mitchell, Esq., Newcastle-on-Tyne	20	0	0
Messrs. North-Eastern Marine Engineering Company, Wallsend-on-Tyne	20	0	0
„ Thomas Richardson & Sons, Hartlepool	20	0	0
„ J. L. Thompson & Sons, Sunderland	20	0	0
„ The Wallsend Slipway Company, Wallsend-on-Tyne	20	0	0
S. P. Austin, Esq., Sunderland	15	0	0
Messrs. Sunderland Shipbuilding Company, Sunderland...	15	0	0
Arthur Coote, Esq., Newcastle-on-Tyne	10	0	0
Messrs. J. Eltringham & Co., South Shields	10	0	0
„ Short Bros., Sunderland (donation)	10	0	0
„ J. Spencer & Sons, Newburn-on-Tyne	10	0	0
„ Clarke, Chapman, & Co., Gateshead-on-Tyne ...	5	0	0
John Gravell, Esq., Newcastle-on-Tyne	5	0	0
Messrs. W. Hepple & Co., North Shields	5	0	0
Hugh Macoll, Esq., Sunderland (three years' subscription)	15	0	0
Messrs. Osbourne, Graham, & Co., Sunderland (donation)	5	0	0
„ J. P. Rennoldson & Co., South Shields	5	0	0
„ Smith's Dock Company, North Shields	5	0	0
„ Westgarth, English, & Co., Middlesbrough ...	5	0	0
„ Baird & Barnsley, North Shields	3	3	0
„ J. Gjemre & Co., Newcastle-on-Tyne	2	2	0
G. E. Macarthy, Esq., Newcastle-on-Tyne	2	2	0
Messrs. J. Priestman & Co., Sunderland	2	2	0
G. W. Sivewright, Esq., Hartlepool	2	2	0
Messrs. Vaughan & Dymond, Newcastle-on-Tyne (donation)	2	2	0
	£453	13	0

Mr. WIGHAM RICHARDSON (Past-President) said he had pleasure in moving the adoption of the Council's report. He thought they must consider it a satisfactory record of what was done during the last session, and, if he might say so, especially as regards the Graduates' section. It seemed to him, at the meetings he attended, that the papers of the Graduates were of a very high order, and the discussions also were quite equal to the discussions among their seniors. His friend, Mr. Taylor, they would see, had been good enough to attend, on behalf of the Institution, at the meetings of the Technical Education Committee of the County Council of Northumberland, and one thing had been done by that Committee which had not received that public notice that he thought it merited. The Committee considered that among so many apprentices in the various works on the north banks of the Tyne, there were some, at least, who might very well be spared by their employers to attend the Durham College of Science during six winter months, arrangements being made for them to go on with their work during the summer months, and with that view offered an Exhibition of £30 for such students. He attended the last meeting with Mr. Taylor, and to their surprise there were only four candidates this session, so that they would have rather an easy time, and competition would be reduced to the minimum; but next year, when it was better known, there would be much keener competition to gain this scholarship, which was for £30 during each year that they attended the classes of the College. He had pleasure in moving the adoption of the report.

The PRESIDENT wished to say, with respect to the list of subscriptions attached to the Council's report, that there were already one or two more to be added, and which would go into next year. The list was not yet closed, and they hoped to have it still further augmented. The report of the Council and the Financial Statement was now before them, was it their pleasure to adopt them?

The report and statement was adopted *nem. con.*

The PRESIDENT then delivered his Inaugural Address:—

PRESIDENT'S ADDRESS.

By ROBERT THOMPSON.

[Delivered in Newcastle-upon-Tyne, on October 10th, 1892.]

I have to thank you for the honour conferred by electing me your President for this session. As the predictions of Mr. Boyd, our first President, have been to a large extent fulfilled, and as this Institution now stands in the front rank of kindred societies, I feel it an honour to occupy this chair.

I shall endeavour to do all I can to further the interests of this Institution, and if enthusiasm and hard work can help forward the aims and objects we have in view, together with the cheerful co-operation of the various officers, I am assured of success.

It may not be out of place to refer briefly to the lamentable cessation of work which was brought about by the differences between the engineers and plumbers, and the stoppage in the coal trade in the County of Durham.

Such stoppages as were experienced during the earlier months of the year are full of disaster to the county, and point to the necessity of forming boards of conciliation, such as exists on the Wear, and which has worked very successfully, so that every effort may be made to come to an amicable agreement without the necessity of reverting to a strike. The men could remain at work during the discussion of the question raised, and so avert that which causes much misery and commercial loss.

This is a question which is deserving of the most serious consideration by all industrial concerns, not only of this district but of the country, and one that will have to be recognised in the future, and I have no doubt would lead to a better understanding between capital and labour.

It is essential to success that capital and labour should recognise that their interests are identical, that strikes and other stoppages encourage foreign competition, and make the struggle to retain our commercial supremacy more severe.

We may be told that this is the "bogie man" again, but it is no use disguising the fact that foreign competition is a reality which has to be faced; for instance, quite recently my firm lost an order which went to

Germany at £1,000 below our net cost, and in this I cannot think that we are singular. It is said that foreigners only build a small percentage of tonnage in comparison with the production of this country, which is true, but it is well to remember that even such a small production leaves so much less for us to build, and affects us greatly in times of depression; it is also an ever-increasing quantity.

My reason for naming these questions of strikes and foreign competition is the fact that they are important elements to consider, as we should avoid weakening our position by internal strife; and by combined effort minimise the effects of outside competition.

Mr. Boyd, in his opening address delivered in November, 1884, sketched out a general idea of what inaugural addresses should be. I propose to-night to follow those suggestions, and I am sure if I can interest you to anything like the extent he did, our time will be well spent.

Historical.

When our first President gave his address our history was beginning; since that time we have as an Institution become established, and the most sanguine must be highly gratified with the progress we have made.

I attribute this success in a great measure to the perfect unanimity that exists amongst the whole of the Past-Presidents, Vice-Presidents, Councillors, Secretary, and members.

Among the objects aimed at by the Institution the following may be mentioned as having been attained, and I think the most of them are of very great importance to this district:—

The measured mile at Whitley-by-the-Sea.

The Engine and Boiler Power Committee have given their report and diagrams relating to powers.

The Shipbuilding Statistical Committee have tabulated statistics up to date.

The reading room and library have been completed, and we are rapidly acquiring a valuable stock of books.

The expectations of our Past-President (Mr. Marshall) and others as to the establishment of a Graduate section have been realised, and it is now a most important adjunct to this Institution. The quality of the papers give great promise for the future when the Graduates pass into full membership; and those of you who have had the pleasure of attending the Graduate meetings must have been struck with the results, showing the high standard of scientific training and the earnestness displayed by all its members.

The chair of Engineering and Naval Architecture has been established, and as a consequence the Durham College of Science maintains close relationship with us, a member of your Council and the President sitting at the College Council.

The fact of our existence resulted in the appointment of four members of the Institution on the Sub-Committee for Surveyors of Lloyd's, a committee that is gradually getting more influence, and by whom good work will be done.

These are a few of the visible effects as the result of the formation of this Institution, but, gentlemen, its influences do not stop here.

It is a fact patent to any observer of the progress of the district that scientific and technical education have received a great impetus since the year 1884.

The varied character of the machinery and vessels constructed show that at last the North-East Coast has proved that, combined with the natural energy of its people, it can produce vessels and machinery requiring the highest possible attainments in the science of engineering and naval architecture.

The standing of the Institution is acknowledged, and its existence strengthens the belief of our customers that we are capable of fulfilling any demands the trade require.

Interesting and valuable statistical and other papers of a practical character have been read and discussed during the past sessions, and have done much to raise the status of the North-East Coast as an engineering and shipbuilding centre. I have no doubt those promised for this session will be equally practical and instructive.

Suggestive.

It remains now for those whose influence can be used in our various County, County Borough, and Borough Councils, to endeavour to secure a portion of the money granted by the Local Taxation (Custom and Excise) Act, to be applied to the purposes of technical education, so that what has been begun by this Institution, and the liberality of some of its members, may be more fully extended.

We hope soon to see an assistant naval architect appointed to co-operate with Professor Weighton, and then Hartlepool, Middlesbro', the Stocktons, and Sunderland may have classes such as were inaugurated by the Durham County Council at Southwick last winter, and which were well attended and highly appreciated.

While ready responses have been made by the local manufacturers to our appeals for help, and which we gratefully acknowledge, we hope that no considerable time will elapse before the district, represented by the Durham College in this city, will not only have a triple or quadruple expansion engine at work (so that practical experiments can be made) but also an experimental tank for ascertaining speeds. I do not see any difficulty as to the working of the latter under the control of the Professor.

It seems quite feasible that on payment of a fixed fee any shipbuilder or engineer could have a model tried and speeds tested.

The difficulty is the want of means for such purposes; these can best be procured by a grant of money from this Institution for the encouragement of original research and investigation, and with the assistance of the capitalists of the North-East Coast, including Hull, Whitby, and Blyth, together with any grant we may obtain from the County Councils.

If Professor Garnett initiated such a scheme, I for one would be glad to assist, and it is worth attempting.

We have had the introduction of iron followed by steel. In introducing the former wood shipbuilding was considerably harassed by the increased requirements of Lloyd's as to scantlings until the trade was practically dead, when Lloyd's suddenly made many concessions to ships built of wood.

On the production of steel the Registry made a reduction of 20 per cent. in its favour.

The following remarkable statement has been made on the authority of a personage well known in the shipbuilding world :—

"No reliable evidence, to my knowledge, has been adduced showing the 20 per cent. reduction from iron admitted by Lloyd's Registry was too great as a maximum."

I once suggested that the introduction of rules for steel vessels was unnecessary, as the scantling for iron and steel vessels would eventually become the same, and this prediction is being fulfilled.

The difference to-day between an ordinary cargo boat built of iron and one of steel is 7 per cent. in favour of the latter, instead of 20 per cent., and every month they more nearly approach each other,

A preference at the present time is given to certain parts of a vessel being of iron instead of steel, such as tank tops and decks exposed to the weather, but my own opinion is that it would be much better to keep the material the same throughout, and I would prefer the steel being of the same thickness as iron in the cases named.

The ordinary life of a ship, as published in a paper devoted to shipbuilding interests, is as follows :—

In the United States	18 years.
„ France	20 „
„ Holland	22 „
„ Germany	25 „
„ Great Britain	26 „
„ Italy	27 „
„ Norway	30 „

The annual death-rate of the world's shipping is about 4 per cent., and the birth-rate 5 per cent.

The foregoing remarks and table will show the varying value of the class assigned by Lloyd's.

I merely place on record the above facts; further on I will give statistics which may be of use to those desiring to investigate the matter, because other materials may soon be introduced.

The changes will be interesting to note.

Whether chrome-nickel or aluminium is to be the future material, or we are to adopt the American plan of coppering, as described in *Fairplay* of 26th August, 1892, are questions full of interest to the manufacturers of this country.

These changes have all a monetary consideration, and manufacturers being without a license have no claim for compensation, hence we often see gaunt walls and empty buildings as evidences of the development of materials and the advances made in special trades.

We have had papers relating to workshops, machines, and tools, thus bearing on the economy of production. I should like to hear additional papers read on these subjects, and think this part of our first President's programme leaves great scope for further contributions, which would doubtless lead to good and profitable discussions.

It would be of great assistance if shipowners or their superintendents could see their way to the reading of papers relating to the working of steamers, referring to their hulls, machinery, deck arrangements, and the appliances for loading and discharging cargo.

Technical.

We have had papers and discussions on almost all the leading subjects under this heading. Those who have followed closely the nature of these, and then compared the actual results of work in the district must have noted that the end of all our efforts has been the production of machinery and vessels of a vastly reduced cost to the purchaser, and this can be proved by comparing the prices of 1889 and 1890 with 1882 and 1883,

Further, while the first cost is so reduced, great economy has been effected in the actual working costs of the machinery and vessels at sea.

It seems to me that on the question of speed we do not make proportionate progress with that on other matters.

How far this is due to the box-like form of ·82 coefficient as adopted by some builders is a question for careful consideration.

Special boats have been built, and from those about to be built for Atlantic companies great results are promised; but if we take the case of the "Umbria," built in 1884, which has recently on her 82nd voyage made the run from Queenstown to Sandy Hook in 5 days 22 hours, although on the fourth day the engines had to be slowed down 10½ hours on account of fog, causing a loss of 3½ hours, which, had the conditions of weather on that day been the same as on other days, the passage would have been made in 5 days 18½ hours, and this by a vessel eight years old without any additional appliance being fitted; the later vessels have only beaten this by 3 or 4 hours; this is the gain in speed we have over a period of eight years.

It is promised that the "Campania" and "Gigantic" shall reduce this considerably, and the latter will have the novelty of three propellers, the introduction of which will be watched with considerable interest, seeing that all admit our knowledge of screw propellers is very uncertain and limited.

The following remarks on this head were made by Mr. W. H. White, Chief Constructor of the Admiralty, in a paper read by him before the members of the Institute of Naval Architects, in April, 1886, on the "Speeds of Recent Warships":—

"These facts furnish another illustration of our want of exact knowledge of the conditions affecting the efficiency of screw propellors, but an attentive study of them cannot fail to be of service to future designing of quick running engines, especially for warships."

Taking these results it seems to me we have gained an addition to speed in Atlantic liners, but at such cost as makes the dividend portion of the undertaking a constantly diminishing quantity, although adding to the luxury of travelling, while in cargo vessels the increased deadweight carried by the modified fuller form of vessels, and the smaller engines fitted have reduced the speed, but with advantage so far as dividend earnings go, although, in my opinion, we are at the extremes, both in the case of the cargo boat and Atlantic liner, which lessens rather than increases the profits.

Whether further extensions of types of engines and boilers with increased pressure await us it is for the future to disclose. Times of depression do often bring about improvements. Let us hope the present will not be an exception.

Types and Forms of Vessels and Variations of same.

Four hundred years ago America was discovered by Columbus, and if we compare the "Santa Maria" with the S.S. "Campania" we shall at once see the development in size and the alteration in form between that period and the present.

Sailing vessels have during the past few years been built of great size and enormous sail area, being fuller in design than formerly, with reduced speed.

Ordinary cargo steamers have developed in dimensions and types to meet the varying demands of trade, and of later years such points as the more equal capacities of holds, and their relation to discharging appliances and time occupied in loading and discharging have been very much taken into consideration, so that practically a vessel can have all holds cleared at the same time. The introduction of web-frames and intercostals doing away with hold beams, thus leaving the holds more clear, and calculations of trim and stability have become universal or nearly so.

Progressive loaded speed trials seem to have been lacking in frequency. This is a question of which owners should realise the usefulness and have fully carried out. It would amply pay them for loss of time and providing cargo to immerse the vessel to her loaded draught, and would supply definite information for determining power for given speed and probably lead to reduced weight of machinery and improvements in the form of propeller which would give more economical results.

By the fuller type of say ·82 coefficient compared with a coefficient of ·74 of ten years ago we have reduced the average speeds by fully 1 knot per hour.

I have had opportunities of comparing vessels and am quite clear that such extreme fulness is no gain. The increase of coefficients from ·74 to ·77 or ·78 shows an advantage so far as the money earning power is concerned.

With a coefficient of ·82 shipowners are simply getting what appears to be a cheaper ship at a rate per ton on the deadweight, but which, in reality, is departing from ship designing to the building of vessels practically without form.

Following up these questions of fulness of model we are led to ask, Is the present form of propeller the most efficient to obtain the

results we aim at, and the type of ship now built the most suitable for the requirements of the trade? The present is a favourable time for the introduction of improvements.

A new type is the patent "turret-deck cargo steamer," now building by one of our Past-Presidents (Mr. W. Theodore Doxford).

We have also the bulk-carrying oil steamer, which has become quite a speciality of the trade.

There has been a gradual increase in the size of vessels, until to-day we have reached 9,000 tons deadweight capacity. We could (from a shipowner) have a very good paper and discussion as to whether 9,000 tons carried in one bottom, or the same carried in two bottoms, will give the best results, say over a period of one year. Low freights prevail. Are they the result of the introduction of larger vessels, or have larger vessels come into use in consequence of low freights? Some may say lower freights means cheaper living for the masses. Yes! but those producing the machinery and vessels; the artizan, shipowners, and sailors must live, and at present freights the outlook is not encouraging.

I have in general terms endeavoured to draw your attention to the existing state of things, and now have the pleasure to give some facts relating to the various classes of vessels. Papers have been read before this and similar institutions dealing with the various types, notably that before the Naval Architects in the year 1891, by Mr. B. Martell, entitled "Alterations in Types and Dimensions of Cargo Steamers," that paper gives the details of the various titles of vessels, so that I need not here repeat them. It is also proved that these alterations in types and dimensions of cargo steamers have not been gained at the expense of seaworthiness, as the figures of total losses at sea have declined relatively to the total number of vessels employed during the same period. The statistics as given will show how the varying demands of trade have developed types; cost also has its influence on types, and thus construction depends on cost and types required to be adapted to suit both the trade and the cost. The tables* will also show how during the last twenty years space and deadweight relate to weight of hull, and therefore to cost.

The idea I had in preparing these tables was that sufficient information is given to formulate new ideas, and with the hope that the result of twenty-two years' experience would lead to further improvements. I am glad to say two members of our staff, appreciating the idea, have offered to read a paper before the Institution, the title of which will be "Types and Proportions of Mercantile Steamers, in relation to Cost, carrying Capacity, and Speed."

* See page 21 *et seq.*

TABLES.

The tables explain themselves, giving deck erections, lengths of double bottom, gross tonnage, which varies in accordance with the different tonnage Acts and decisions recorded from the year 1854 to 1889, and also in proportion to the length of deck erections, net weight of material, equipment weight, weight of engines and boilers with water in, displacement and coefficient, and draught exclusive of keel, based on Lloyd's present *freeboard tables*. I started with the idea that Lloyd's scantlings had not increased *pro rata* with the variations of vessels, but the results prove the opposite. In making comparisons on this head, the question of iron *versus* wood decks, extent of double bottom, number of bulkheads (so far as the latter are concerned nearly all those given in the tables have six bulkheads, a few five, and a very small number four, the latter in the earlier ships only). Deck erections in many cases are of iron and occasionally of wood; but by keeping out exceptional ships the differences do not amount to much, except in the cases of vessels having double bottoms fore and aft, when compared with those having partial double bottoms. The gain in deadweight of the more modern boats seems to be entirely due to the slightly fuller design, the introduction of steel, especially in the earlier vessels built of this material, and also in the lighter engines of the triple-expansion type, as compared with the old compound. The partial awning-decked vessel, made by simply joining the bridge and forecastle, gives a large increase in the deadweight on a small weight of material. I should like to see papers read on the result of the information given, both from shipbuilders, engineers, and ship superintendents.

If any owner would give us the average indicated horse-power, speed, etc., from the actual experience gained with his vessels, a very instructive discussion would ensue. I should have liked to have dealt with costs showing the relative values, but in the paper promised these will be discussed more effectively than I could hope to do in an address. I also append the chart of Mediterranean grain freights from 1883 to 1891, taken from Messrs. McNabb, Rouqier, & Co.'s circular (Plate I.), and prices of iron and steel plates and angles from 1884 to 1891 (Plate II.). I have only one other remark to make, and that refers to the paper I had the honour to read before the Institution in the year 1887. In the tables of that paper distances were calculated up to 12,000 miles. During the discussion that followed it was stated as very unlikely that a vessel would do such distances without bunkering. I may state that the S.S. "Fulwell," built by my firm, has done this, and very satisfactorily to all interested.

As to which is the best of the present types is a question worthy of discussion. I do not allude to the whale back, of which I have not a high opinion, believing that if we take all the outfit, hatches, bulwarks, etc., from any of the present types, we have a cheaper vessel; but we want more than a mere hull to do the carrying trade across the Atlantic. The improved appliances for loading and discharging vessels renders the type having 'tween decks less objectionable now than formerly; thus at present the partial awning-deck vessel practically has the double deck fore and aft, and the ordinary raised quarter-deck (except for coasting purposes) is fast becoming obsolete. The question for consideration is whether the spar-deck type is the most suitable both as regards structural strength and adaptability for the merchant service. This is for the shipowner to decide. We, as constructors, can only point out the facts with the view of producing the best possible type of vessel suitable for long oversea voyages.

Some modification of the gross tonnage of the spar-deck vessel should be granted by the Board of Trade, especially when they are loaded with deadweight cargoes. This is an important point and ought to be considered by the Board. A tonnage for the vessel when so laden could be stated on the usual certificate, or a separate one could be issued, as in the case of vessels trading through the Suez Canal. Shipowners would thus be encouraged to adopt the type having the largest amount of surplus buoyancy, and therefore a much more seaworthy vessel.

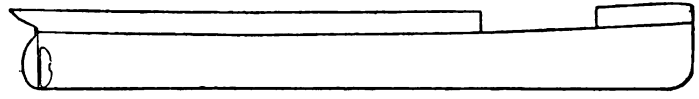
I have to thank you for your attention, and trust that any hints I have thrown out as to the direction of our future work or enquiries may be accepted in the spirit in which they are intended, and if anything I have said may lead to a greater interest being taken in the Institution, and an impetus given to the study of the problems daily surrounding us, our time will not have been ill spent and my labour will be amply repaid.

FLUSH-DECK, LONG FULL POOP.

No.	Description.		Wood Decks.	Water Ballast.	Weight of Material.	Weight of Outfit.	Weight of Engines.	Complete Light Weight.	Total Deadweight.	Skin Displacement.	Coefficient of Displacement.	Draft, ex Keel.	Deadweight. Weight of Material.	Deadweight. Weight of Material and Outfit.	Deadweight. Light Weight.	Gross Tonnage.	Gross Tonnage. Weight of Material.	Gross Tonnage. Weight of Material and Outfit.	Gross Tonnage. Light Weight.	Gross Cubic Capacity.	Cubic Ft. per Ton on D.W.	Year.
	Ft. In.	Ft. In.		% of Length.								Ft. In.										
1	Poop, 121 0	F'castle, 23 0	M., P., & F'cle.	McT., 35·81	416	63	127	605	1,495	2,100	·704	16 4½	3·59	3·12	2·47	1,007	2·42	2·10	1·66	63,705	42·61	1871
2	„ 122 8	„ 24 4	„ „ „	„ 39·18	464	108	152	724	1,529	2,253	·716	16 0	3·29	2·67	2·11	1,112	2·39	1·94	1·54	68,134	44·56	„
3	„ 117 4	„ 23 8	„ „ „	„ 40·16	374	146	104	624	1,243	1,868	·696	15 2	3·32	2·39	1·99	910	2·43	1·75	1·46	63,976	51·47	1872
4	„ 125 0	„ 30 0	„ „ „	„ 41·81	441	96	131	668	1,480	2,148	·711	16 0	3·35	2·75	2·21	1,065	2·41	1·98	1·59	65,520	44·27	„
5	„ 125 0	„ 29 0	„ „ „	„ 41·81	433	94	131	658	1,485	2,143	·704	15 11½	3·43	2·82	2·25	1,080	2·49	2·05	1·64	66,560	44·82	1873
6	„ 122 0	„ 27 0	„ „ „	„ 41·8	446	89	131	666	1,424	2,090	·709	15 11	3·19	2·66	2·14	1,051	2·36	1·96	1·58	65,520	46·01	„
7	„ 126 6	„ 27 0	M.F., P., & F.	„ 64·3	545	235	140	920	1,363	2,283	·740	15 10	2·50	1·74	1·48	1,186	2·18	1·52	1·29	72,952	53·52	1884
8	„ 148 0	„ 26 6	Poop & F'cle.	Cell., 72·8	785	254	185	1,224	1,948	3,172	·732	17 4	2·48	1·87	1·59	1,562	1·99	1·50	1·28	110,378	56·66	1885
	All built of iron.																					

SHOWING THE HIGHEST AND LOWEST DEADWEIGHTS COMPARED WITH WEIGHT OF MATERIAL.

1	Poop, 121 0	F'castle, 23 0	M., P., & F'cle.	McT. 35·81	416	63	127	605	1,495	2,100	·704	16 4½	3·59	3·12	2·47	1,007	2·42	2·10	1·66	63,705	42·61	1871
8	„ 148 0	„ 26 6	Poop & F'cle.	Cell., 72·8	785	254	185	1,224	1,948	3,172	·732	17 4	2·48	1·87	1·59	1,562	1·99	1·50	1·28	110,378	56·66	1885

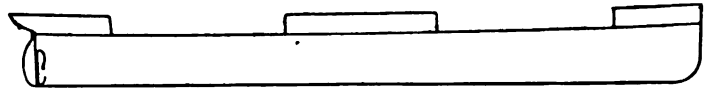


FLUSH-DECK.

No.	Description.	Wood Decks.	Water Ballast.	Weight of Material.	Weight of Outfit.	Weight of Engines.	Complete Light Weight.	Total Deadweight.	Skin Displacement.	Coefficient of Displacement.	Draft, ex Keel.	Deadweight. Weight of Material.	Deadweight. Weight of Material and Outfit.	Deadweight. Light Weight.	Gross Tonnage.	Gross Tonnage. Weight of Material.	Gross Tonnage. Weight of Material and Outfit.	Gross Tonnage. Light Weight.	Gross Cubic Capacity.	Cubic Ft. per Ton on D.W.	Year.
	Ft. In. Ft. In. Ft. In.		% of Length.								Ft. In.										
1	P. 30 8, B. 42 2, F. 25 2	M., P., B., & F.	McT., 48·78	439	98	131	668	1,440	2,108	·709	15 9	3·28	2·68	2·15	963	2·20	1·79	1·44	65,520	45·50	1872
2	„ — „ 55 0, „ 17 0	M., B., & F.	„ 46·5	437	227	136	800	1,114	1,914	·724	14 11½	2·55	1·67	1·39	894	2·05	1·35	1·12	53,158	50·57	1877
3	„ 28 0, „ 56 0, „ 29 6	Poop.	„ 66·91	966	273	246	1,485	2,502	3,987	·725	18 7½	2·59	2·02	1·68	1,895	1·96	1·53	1·28	130,144	55·05	1879
4	„ 36 0, „ 54 0, „ 29 6	„	„ 67·17	853	247	192	1,292	2,121	3,413	·721	17 8¾	2·48	1·93	1·64	1,664	1·95	1·51	1·29	118,303	59·00	„
5	„ 32 0, „ 56 0, „ 28 0	„	„ 53·07	880	248	214	1,342	2,341	3,683	·726	19 0½	2·66	2·07	1·74	1,744	1·98	1·54	1·30	118,197	53·40	1880
6	„ 28 0, „ 52 0, „ 25 6	None.	„ 51·32	981	307	210	1,498	2,784	4,282	·774	17 11¼	2·83	2·16	1·86	2,057	2·10	1·60	1·38	182,090	65·44	„
7	„ 28 0, „ 46 0, „ 26 6	„	„ 50·00	796	226	165	1,187	1,937	3,124	·753	16 7	2·43	1·89	1·63	1,475	1·85	1·44	1·24	106,122	54·73	„
8	„ 28 0, „ 46 0, „ 28 3	„	„ 51·53	856	211	165	1,232	2,176	3,408	·755	16 10½	2·54	2·04	1·76	1,688	1·97	1·58	1·37	116,112	53·36	„
9	„ 28 0, „ 52 0, „ 26 6	„	„ 52·5	1,245	230	240	1,515	2,759	4,274	·761	18 7¼	2·21	1·87	1·82	2,056	1·65	1·40	1·35	148,627	53·87	1881
10	„ 48 0, „ 55 0, „ 24 6	P., M., & F.	Cell., 74·2	731	465	187	1,383	1,546	2,929	·723	16 4	2·11	1·29	1·12	1,372	1·88	1·15	·99	86,891	56·20	„
11	„ 23 0, „ 44 0, „ 24 0	Poop.	McT., 51·1	637	260	152	1,059	1,448	2,507	·751	13 11¼	2·27	1·61	1·37	1,214	1·91	1·35	1·14	82,832	57·20	1882
12	„ 28 0, „ 64 0, „ 27 6	None.	„ 52·8	972	266	219	1,457	2,471	3,928	·753	17 9¼	2·54	1·99	1·69	1,980	2·04	1·60	1·36	141,279	57·17	„
	All built of iron.																				

Showing the Highest and Lowest Deadweights compared with Weight of Material.

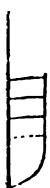
1	P. 30 8, B. 42 2, F. 25 2	M., P., B., & F.	McT., 48·78	439	98	131	668	1,440	2,108	·709	15 9	3·28	2·68	2·15	963	2·20	1·79	1·44	65,520	45·50	1872
10	„ 48 0, „ 55 0, „ 24 6	P., M., & F.	Cell, 74·2	731	465	187	1,383	1,546	2,929	·723	16 4	2·11	1·29	1·12	1,372	1·88	1·15	·99	86,891	56·20	1881



eight.		Gross Tonnage.	Gross Tonnage.			Gross Cubic Capacity.	Cubic Ft. per Ton on D.W.	Year.
and Outfit.	Light Weight.		Weight of Material.	Weight of Material and Outfit.	Light Weight.			
93	2·16	1,064	2·11	1·65	1·37	77,644	46·41	1874
12	1·958	1,622	2·03	1·53	1·28	134,983	54·36	1876
37	2·173	1.688	1·96	1·68	1·41	122,485	47·20	1877
5	2·090	2,024	2·03	1·60	1·37	155.252	50·13	„
3	2·230	1,750	2·02	1·83	1·50	131,000	50·25	1878
3	2·086	1,512	2·05	1·64	1·35	108,394	46·40	„
06	2·145	1,695	2·03	1·71	1·41	119,301	46·33	1879
r	2·00	2,010	2·11	1·63	1·38	143,516	49·11	„
3	1·95	2,085	2·09	1·63	1·40	155,669	53·44	1880
3	1·98	2,173	2·08	1·59	1·38	147,044	47·14	1883
22	1·904	2,610	2·01	1·57	1·35	184,734	50·09	„
7	1·974	2,205	2·05	1·61	1·40	152,054	48·83	„
r	2·06	2,914	2·03	1·49	1·29	235,427	50·60	1885
13	1·855	2,467	1·99	1·44	1·24	181,316	49·61	„
5	1·91	2,833	2·06	1·57	1·32	215,175	52·57	1886
)	2·08	2,155	2·15	1·68	1·41	157,267	49·21	1887
5	2·09	2,454	2·03	1·56	1·33	203,970	52·83	„
08	1·887	2.836	2·17	1·59	1·31	215,842	52·84	„
2	1·975	2,937	1·99	1·53	1·25	266,654	57·57	1889
r	2·096	3,892	2·25	1·76	1·50	305,882	56·13	1890
3	1·946	4,010	2·37	1·79	1·50	314,157	60·23	1891

f OF MATERIAL.

93	2·16	1,064	2·11	1·65	1·37	77,644	46·41	1874
22	1·904	2,610	2·01	1·57	1·35	184,734	50·09	1883



SPAR-DECK TYPE.

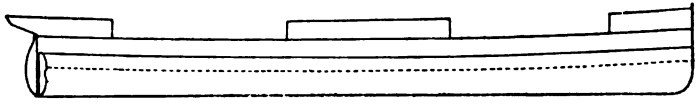
No.	Description.	Wood Decks.	Water Ballast.	Weight of Material.	Weight of Outfit.	Weight of Engines.	Complete Light Weight.	Total Deadweight.	Skin Displacement.	Coefficient of Displacement.	Draft, ex Keel.		Deadweight. Weight of Material.	Deadweight. Weight of Material and Outfit.	Deadweight. Light Weight.	Gross Tonnage.	Gross Tonnage. Weight of Material.	Gross Tonnage. Weight of Material and Outfit.	Gross Tonnage. Light Weight.	Gross Cubic Capacity.	Cubic Ft. per Ton on D.W.	Year.
			% of Length.								Ft.	In.										
1	No Erections.	Spar & Main.	McT., 53·83	554	184	152	890	2,078	2,968	·743	19	2	3·75	2·81	2·33	1,356	2·45	1·84	1·52	95,755	46·08	1872
2	" "	" "	" 42·40	531	176	169	876	1,899	2,775	·711	18	9	3·57	2·68	2·17	1,311	2·46	1·85	1·49	96,600	50·87	1873
3	" "	S. & M'ky. F'cl.	" 46·0	621	206	176	1,003	2,211	3,214	·713	19	8½	3·56	2·67	2·20	1,442	2·32	1·74	1·43	108,170	48·92	1874
4	" "	Monkey Forec'l.	" 53·3	1,336	334	275	1,945	4,446	6,391	·766	24	2¼	3·33	2·66	2·29	2,921	2·19	1·75	1·50	226,311	50·90	1882
5	" "	" "	" 80·6	1,414	409	325	2,148	4,141	6,289	·741	23	7	2·93	2·27	1·92	2,902	2·05	1·59	1·35	210,429	50·81	"
6	" "	S. & M'ky. F'cl.	Cell., 72·7	1,614	496	355	2,465	4,656	7,121	·743	23	4½	2·89	2·21	1·89	3,170	1·96	1·50	1·29	246,943	53·03	1883
7	" "	" " "	" 72·0	1,389	447	312	2,148	4,022	6,170	·737	23	3	2·89	2·19	1·87	2,870	2·07	1·57	1·33	211,677	52·62	"
8	Ft. Ft. Ft. Poop 72, Bridge 94, F'cle. 50	S.,M.,P., B., & F.	" 80·0	1,600	743	557	2,900	4,495	7,395	·709	23	7	2·80	1·92	1·55	3,555	2·22	1·52	1·23	248,171	55·21	1888
9	" 30, " 76, " 36	P., Bridge, & F.	" 79·33	1,236	385	288	1,909	4,083	5,992	·756	22	6½	3·30	2·52	2·14	2,728	2·21	1·68	1·42	234,112	57·33	1891
10	" 32, " 58, " 32½	" " "	" 81·21	1,380	380	295	2,055	4,080	6,635	·764	21	4	2·95	2·32	1·98	3,080	2·23	1·75	1·50	238,727	52·12	1892

1-8, built of iron; 9 and 10, steel.

Showing the Highest and Lowest Deadweights compared with Weight of Material.

1	No Erections.	Spar & Main.	McT., 53·83	554	184	152	890	2,078	2,968	·743	19	2	3·75	2·81	2·33	1,356	2·45	1·84	1·52	95,755	46·08	1872
8	Poop 72, Bridge 94, F'cle. 50	S.,M.,P., B., & F.	Cell., 80·0	1,600	743	557	2,900	4,495	7,395	·709	23	7	2·80	1·92	1·55	3,555	2·22	1·52	1·23	248,171	55·21	1888

Both iron.

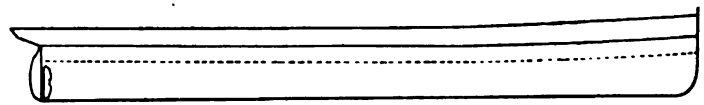


AWNING DECK CLASS.

No.	Description.	Wood Decks.	Water Ballast.	Weight of Material.	Weight of Outfit.	Weight of Engines.	Complete Light Weight.	Total Deadweight.	Skin Displacement.	Coefficient of Displacement.	Draft, ex Keel. Ft.	Draft, ex Keel. In.	Deadweight. Weight of Material.	Deadweight. Weight of Material and Outfit.	Deadweight. Light Weight.	Gross Tonnage.	Gross Tonnage. Weight of Material.	Gross Tonnage. Weight of Material and Outfit.	Gross Tonnage. Light Weight.	Gross Cubic Capacity.	Cubic Ft. per Ton on D.W.	Year.
			% of Length.																			
1	Awning Deck—Iron.	Awning, Lower, & Monkey Forecastle.	C.B., 75·0	1,454	472	344	2,270	3,238	5,508	·696	21	6	2·23	1·68	1·43	2,638	1·81	1·37	1·16	205,132	63·35	1881
2	" " "	" " "	McT. 51·93	1,090	293	252	1,635	3,229	4,864	·733	21	8¼	2·96	2·33	1·98	2,374	2·18	1·78	1·45	188,541	55·29	"
3	" " "	" " "	C.B., 76·0	1,386	379	345	2,110	3,410	5,520	·697	21	6½	2·46	1·93	1·62	2,601	1·88	1·48	1·23	208,473	61·14	"
4	" " "	Mky. F'castle.	" 81·1	1,173	365	232	1,770	3,072	4,842	·751	21	3¾	2·62	2·00	1·73	2,424	2·07	1·58	1·37	187,412	61·02	1882
5	" " "	Awning covered with wood, Bridge, & Mky. F'castle.	" 84·37	1,380	421	287	2,088	3,890	5,978	·760	21	6	2·82	2·16	1·86	2,959	2·14	1·64	1·42	225,559	58·00	"
6	" " Steel.	Awning.	" 72·8	706	289	185	1,180	2,156	3,336	·711	18	1	3·05	2·17	1·83	1,743	2·47	1·75	1·48	128,586	59·64	1887
7	" " "	"	" 61·71	426	224	120	770	1,088	1,858	·753	14	0½	2·55	1·67	1·41	1,026	2·41	1·58	1·33	73,717	67·75	1890
8	" " "	"	" 72·8	732	305	185	1,222	2,315	3,537	·752	18	3½	3·16	2·23	1·89	1,817	2·48	1·75	1·49	134,282	58·01	1891

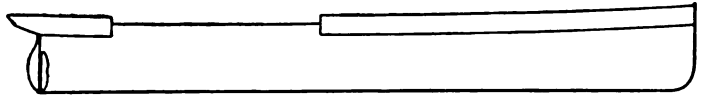
SHOWING THE HIGHEST AND LOWEST DEADWEIGHTS COMPARED WITH WEIGHT OF MATERIAL.

1	Awning Deck—Iron.	Awning, Lower, & Monkey Forecastle.	C.B., 75·0	1,454	472	344	2,270	3,238	5,508	·696	21	6	2·23	1·68	1·43	2,638	1·81	1·37	1·16	205,132	63·35	1881
8	" " —Steel.	Awning.	" 72·8	732	305	185	1,222	2,315	3,537	·752	18	3½	3·16	2·23	1·89	1,817	2·48	1·75	1·49	134,282	58·01	1891



PARTIAL AWNING-DECK CLASS.

No.	Description.	Wood Decks.	Water Ballast.	Weight of Material.	Weight of Outfit.	Weight of Engines.	Complete Light Weight.	Total Deadweight.	Skin Displacement.	Coefficient of Displacement.	Draft, ex Keel.	Deadweight. Weight of Material.	Deadweight. Weight of Material and Outfit.	Deadweight. Light Weight.	Gross Tonnage.	Gross Tonnage. Weight of Material.	Gross Tonnage. Weight of Material and Outfit.	Gross Tonnage. Light Weight.	Gross Cubic Capacity.	Cubic Ft. per Ton on D.W.	Year.
	Ft.										Ft. In.										
1	Poop 28, Partial Awng. 173½, Qr. 72	Poop, Y. Pine.	%, of Length. McT. 50·18	910	328	248	1,486	3,169	4,655	·759	20 6½	3·48	2·69	2·13	2,057	2·26	1·66	1·39	166,027	52·40	1888
2	„ 28, „ 182½, „ 72	„ „ „	C.B. 74	899	267	219	1,385	3,134	4,516	·756	19 4½	3·48	2·68	2·26	1,942	2·16	1·67	1·40	166,767	53·26	„
3	„ 28, „ 180, „ 74	„ „ „	McT. 51·4	880	256	239	1,375	3,157	4,532	·757	19 5	3·58	2·77	2·29	2,081	2·36	1·83	1·51	167,843	53·16	1889
4	„ 28, „ 180, „ 80	„ „ „	C.B. 76·55	975	318	253	1,546	3,494	5,040	·762	20 7¾	3·58	2·70	2·26	2,172	2·23	1·68	1·41	184,234	52·73	„
5	„ 28, „ 173½, „ 72	„ „ „	McT. 50·18	902	314	244	1,460	3,182	4,642	·755	20 7	3·53	2·61	2·18	2,071	2·29	1·70	1·42	166,548	52·34	„
6	„ 28, „ 180½, „ 74	„ „ „	C.B. 74·64	885	262	230	1,377	3,133	4,510	·754	19 4¾	3·54	2·73	2·27	1,957	2·21	1·71	1·42	165,639	52·87	„
7	„ 28, „ 198, „ 88	„ „ „	„ 72·78	1,138	313	282	1,733	4,241	5,974	·759	21 6	3·72	2·92	2·44	2,606	2·29	1·79	1·50	229,040	54·00	„
8	„ 28, „ 174, „ 88	„ „ „	„ 80·82	975	335	265	1,575	3,562	5,137	·782	20 2¼	3·65	2·72	2·26	2,193	2·25	1·67	1·39	187,100	52·53	„
9	„ 28, „ 180½, „ 74	„ „ „	„ 74·64	901	301	238	1,440	3,085	4,525	·759	19 4	3·42	2·56	2·14	2,071	2·30	1·72	1·44	170,047	55·12	„
10	„ 28, „ 182½, „ 72	„ „ „	„ 72·53	915	288	229	1,432	3,089	4,521	·755	19 5	3·37	2·56	2·16	2,061	2·25	1·71	1·44	166,950	54·05	1890
11	„ 28, „ 183½, „ 78	„ „ „	McT. 51·72	986	307	227	1,520	3,388	4,908	·759	20 0	3·43	2·62	2·23	2,407	2·44	1·86	1·58	191,120	56·41	„
12	„ 28, „ 180½, „ 74	„ „ „	„ 51·4	908	292	230	1,430	3,113	4,543	·759	19 5	3·42	2·59	2·18	2,138	2·34	1·78	1·49	166,050	53·34	„
13	„ 28, „ 182¼, „ 88	„ „ „	C.B. 72	1,061	325	236	1,622	3,738	5,360	·774	20 2¼	3·52	2·69	2·30	2,514	2·37	1·81	1·55	200,910	53·48	„
14	„ 28, „ 198¼, „ 88	„ „ „	„ 70·88	1,224	366	310	1,900	4,176	6,076	·769	21 7	3·41	2·62	2·19	2,825	2·31	1·78	1·49	229,548	54·97	„
15	„ 24, „ 185, „ 80	„ „ „	„ 75·2	1,034	327	229	1,590	3.574	5,164	·778	19 5½	3·45	2·62	2·25	2,308	2·23	1·70	1·45	187,421	52·44	„
16	„ 28, „ 183, „ 80	„ „ „	McT. 68·49	1,043	294	253	1,590	3,552	5,142	·785	20 1½	3·40	2·65	2·23	2·404	2·30	1·79	1·51	191,625	53·95	1891
17	„ 28, „ 180½, „ 80	„ „ „	„ 51	1,043	329	250	1,622	3,530	5,152	·777	20 8	3·38	2·57	2·17	2·363	2·26	1·72	1·46	186,750	52·90	„
18	„ 28, „ 167, „ 78	„ „ „	„ 45·8	886	301	227	1,414	2.900	4,314	·760	19 2½	3·27	2·44	2·05	2·069	2·34	1·74	1·46	163,680	56·44	„
19	„ 28, „ 173¼, „ 72	„ „ „	C.B. 78·54	884	256	230	1,360	2,912	4,272	·7617	18 9½	3·29	2·55	2·14	2·039	2·31	1·79	1·50	161,499	55·46	„
20	„ 28, „ 192½, „ 100	„ „ „	„ 72·67	1,318	361	281	1,960	4,469	6,429	·7681	21 11	3·39	2·66	2·28	3·030	2·30	1·80	1·55	249,677	55·87	„
	All built of steel.																				
	SHOWING THE HIGHEST AND LOWEST DEADWEIGHTS COMPARED WITH WEIGHT OF MATERIAL.																				
7	Poop 28, Bridge 198, Qr. 88	Poop, Y. Pine	C.B. 72·78	1,138	313	282	1,733	4,241	5,974	·759	21 6	3·72	2·92	2·44	2·606	2·29	1·79	1·69	229,040	54·00	1889
18	„ 28, „ 167, „ 78	„ „ „	McT. 45·8	886	301	227	1,414	2,900	4,314	·760	19 2½	3·27	2·44	2·05	2·069	2·34	1·74	1·46	163,680	56·44	1891

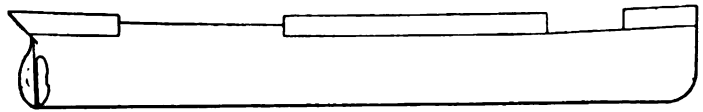


RAISED QUARTER-DECK LONG BRIDGE CLASS.

No.	Description.	Wood Decks.	Water Ballast.	Weight of Material.	Weight of Outfit.	Weight of Engines.	Complete Light Weight.	Total Deadweight.	Skin Displacement.	Coefficient of Displacement.	Draft, ex Keel.		Deadweight. Weight of Material.	Deadweight. Weight of Material and Outfit.	Deadweight. Light Weight.	Gross Tonnage.	Gross Tonnage. Weight of Material.	Gross Tonnage. Weight of Material and Outfit.	Gross Tonnage. Light Weight.	Gross Cubic Capacity.	Cubic Ft. per Ton on D.W.	Year.
			% of Length.								Ft.	In.										
1	½P. 24′, R.Q. 76′, L.B., 112′, Open T.G.F. 27′ 6″ ...	Poop	C.B. 74·9	866	246	165	1,277	2,607	3,884	·746	18	1¾	3·01	2·34	2·04	1,752	2·02	1·57	1·37	140,858	54·03	1886
	Ft. Ft. Ft. In. Ft.																					
2	R.Q.P. 28, B. 118, F. 26 6, Q. 84	„	McT. 69	968	268	219	1,455	2,978	4,433	·752	19	1¼	3·07	2·41	2·04	2,122	2·19	1·72	1·46	158,793	53·32	1887
3	„ 28, „ 114, „ 29 0, „ 72	„	„ 50·18	868	358	240	1,466	3,020	4,486	·751	20	0	3·48	2·46	2·06	2,129	2·45	1·74	1·45	156,361	51·77	„
4	„ 28, „ 118, „ 26 0, „ 82	„	C.B. 74·64	842	278	223	1,343	3,140	4,483	·755	19	3	3·72	2·80	2·34	1,973	2·34	1·76	1·47	159,228	50·71	„
5	„ 28, „ 122, „ 32 4, „ 80	„	„ 83·45	948	341	262	1,551	3,445	4,996	·763	20	5½	3·63	2·67	2·22	2,216	2·34	1·72	1·43	174,493	50·65	1888
6	„ 32, „ 126, „ 32 0, „ 80	„	McT. 51·33	961	279	260	1,500	3,460	4,960	·757	19	7	3·60	2·79	2·30	2,334	2·43	1·88	1·56	180,628	52·20	„
7	„ 28, „ 122, „ 32 4, „ 80	„	„ 51·034	963	294	268	1,525	3,443	4,968	·761	20	4½	3·57	2·74	2·25	2,327	2·42	1·85	1·52	177,399	51·52	„
8	„ 28, „ 126, „ 26 6, „ 74	„	„ 51·4	852	268	225	1,345	3,110	4,455	·755	19	1½	3·65	2·77	2·31	2,064	2·42	1·84	1·53	159,881	51·40	„
9	„ 28, „ 126, „ 26 0, „ 74	„	C.B. 74·647	874	253	220	1,350	3,115	4,465	·757	19	1½	3·56	2·76	2·31	1,979	2·27	1·76	1·47	159,504	51·19	„
10	„ 28, „ 114, „ 35 6, „ 72	„	McT. 50·18	897	317	246	1,460	3,096	4,556	·752	20	3½	3·45	2·55	2·12	2,128	2·37	1·75	1·46	160,129	51·18	„
11	„ 28, „ 118, „ 29 6, „ 72	„	„ 50·54	830	282	238	1,350	2,857	4,207	·743	19	3	3·44	2·57	2·11	1,969	2·37	1·77	1·46	153,101	53·58	„
12	„ 28, „ 122, „ 32 0, „ 80	„	„ 52·41	966	282	242	1,490	3,461	4,951	·762	20	4	3·58	2·77	2·32	2,242	2·32	1·79	1·50	178,210	51·49	„
13	„ 28, „ 118, „ 30 0, „ 82	„	„ 69	886	276	226	1,388	3,048	4,436	·755	19	0½	3·44	2·62	2·19	2,022	2·28	1·74	1·46	159,095	52·19	1889
14	„ 28, „ 124, „ 33 0, „ 80	„	C.B. 76·02	973	342	259	1,574	3,504	5,078	·782	19	11½	3·60	2·66	2·22	2,159	2·22	1·64	1·37	179,068	51·10	„
	All built of steel.																					

Showing the Highest and Lowest Deadweights compared with Weight of Material.

1	½P. 24′, R.Q. 76′, L.B, 112′, Open T.G.F. 27′ 6″ ...	Poop	C.B. 74·9	866	246	165	1,277	2,607	3,884	·746	18	1¾	3·01	2·34	2·04	1,752	2·02	1·57	1·37	140,858	54·03	1886
4	„ P. 28′, B. 118′, F. 26′, Q. 82′	„	„ 74·64	842	278	223	1,343	3,140	4,483	·755	19	3	3·72	2·80	2·34	1,973	2·34	1·76	1·47	159,228	50·71	1887

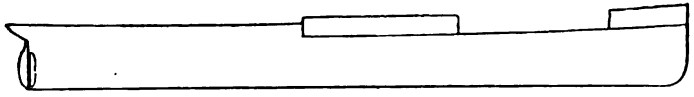


LONG RAISED QUARTER-DECK.

No.	Description.	Wood Decks.	Water Ballast.	Weight of Material.	Weight of Outfit.	Weight of Engines.	Complete Light Weight.	Total Deadweight.	Skin Displacement.	Coefficient of Displacement.	Draft, ex Keel.	Deadweight. Weight of Material.	Deadweight. Weight of Material and Outfit.	Deadweight. Light Weight.	Gross Tonnage.	Gross Tonnage. Weight of Material.	Gross Tonnage. Weight of Material and Outfit.	Gross Tonnage. Light Weight.	Gross Cubic Capacity.	Cubic Ft. per Ton on D.W.	Year
	Ft. Ft. Ft.		% of Length.								Ft. In.										
1	Q.D. 111, B. 12, F. 24	F., M., & Q.	McT., 56·9	429	116	131	676	1,124	1,800	·718	14 7½	2·62	2·06	1·66	853	1·99	1·56	1·26	56,305	50·09	1875
2	„ 123⅓, — „ 30	„ „	„ 54·01	509	157	134	800	1,380	2,180	·705	15 10½	2·71	2·07	1·73	1,036	2·03	1·56	1·29	70,722	51·25	1876
3	„ 85, „ 45, „ 27	R.Q. & F.	„ 46·66	615	119	156	890	1,708	2,598	·754	16 7½	2·78	2·32	1·92	1,214	1·97	1·65	1·36	87,285	51·10	1877
4	„ 88, „ 46, „ 25¾	M., R.Q., & F.	„ 51·6	661	181	173	1,015	1,733	2,748	·721	16 8¾	2·62	2·05	1·70	1,288	1·95	1·53	1·26	91,140	52·59	1880
5	„ 100, „ 58, „ 26½	R.Q. to frame 16	„ 53·0	805	255	182	1,242	2,320	3,562	·752	17 8½	2·88	2·19	1·87	1,697	2·11	1·60	1·37	119,095	51·33	1883
	All built of iron.																				

SHOWING THE HIGHEST AND LOWEST DEADWEIGHTS COMPARED WITH WEIGHT OF MATERIAL.

1	Q.D. 111, B. 12, F. 24	F., M., & Q.	McT., 56·9	429	116	131	676	1,124	1,800	·718	14 7½	2·62	2·06	1·66	853	1·99	1·56	1·26	56,305	50·09	1875
5	„ 100, „ 58, „ 26½	R.Q. to frame 16	„ 53·0	805	255	182	1,242	2,320	3,562	·752	17 8½	2·88	2·19	1·87	1,697	2·11	1·60	1·37	119,095	51·33	1883



eight.			Gross Tonnage.					
and Outfit.	Light Weight.	Gross Tonnage.	Weight of Material.	Weight of Material and Outfit.	Light Weight.	Gross Cubic Capacity.	Cubic Ft. per Ton on D.W.	Year.
8	1·62	1,406	2·03	1·49	1·28	102,755	57·72	1878
4	1·65	1,306	2·02	1·52	1·29	98,235	58·93	,,
5	1·78	1,382	2·05	1·58	1·31	93,995	50·05	,,
8	1·86	2,014	2·05	1·61	1·38	155,570	57·19	1879
4	1·72	1,411	1·96	1·51	1·27	100,033	52·34	,,
3	1·77	1,418	1·98	1·55	1·29	100,442	51·37	1880
8	1·83	1,562	2·01	1·54	1·30	118,782	53·79	,,
7	1·89	1,707	2·07	1·57	1·37	123,200	52·13	,,
2	1·68	1,343	1·98	1·43	1·25	95,524	52·89	,,
1	1·77	1,697	2·02	1·59	1·33	118,853	52·59	1881
8	1·59	1,415	1·97	1·44	1·22	98,725	53·45	,,
0	1·79	1,964	2·11	1·58	1·34	141,075	54·01	,,
5	1·86	1,862	2·10	1·58	1·37	132,668	52·38	1882
7	1·59	1,533	2·02	1·47	1·25	96,626	49·45	,,
4	1·55	1,385	1·78	1·42	1·19	91,999	50·97	,,
2	1·81	1,704	2·07	1·57	1·34	118,467	51·35	,,
8	1·77	2,003	2·13	1·59	1·36	146,168	55·85	,,
1	1·66	1,221	2·04	1·52	1·32	79,689	51·82	1883
9	1·54	1,571	1·86	1·39	1·19	112,831	55·63	,,
6	1·78	1,725	2·16	1·57	1·36	121,259	53·44	,,
6	1·93	1,986	2·17	1·66	1·41	139,028	50·15	,,
2	1·90	2,158	2·17	1·69	1·45	157,136	55·52	,,
0	1·70	1,762	2·13	1·58	1·34	114,064	50·92	,,
2	1·74	1,526	2·06	1·56	1·35	104,873	53·10	1884
3	1·76	1,521	2·05	1·52	1·32	105,386	51·90	,,
5	1·84	1,753	2·05	1·57	1·34	122,481	50·91	1885
7	1·87	1,924	2·06	1·58	1·36	138,521	52·35	,,
2	1·88	1,627	1·98	1·53	1·30	124,505	52·85	1886
8	1·89	1,911	2·02	1·55	1·34	141,351	52·41	,,

OF MATERIAL.

4	1·55	1,385	1·78	1·42	1·19	91,999	50·97	1882
6	1·93	1,986	2·17	1·66	1·41	139,028	50·15	1883

VOTE OF THANKS TO PRESIDENT.

Mr. HUGH MACOLL said he was sure they must have listened with great attention, and also with great profit, to the very excellent address delivered by their new President. He had gone over a considerable range of observation, treating his subject, he might say, with a master-hand, and yet left ample scope for any who might be concerned to step in and fill up the gaps. The address was very suggestive, and the tables were also suggestive of a very considerable amount of research, and a lot of hard work in collecting and arranging the data set forth. It would take a great deal of study and application to master them as they stood without attempting to offer observations upon them. He could only say that they were exceedingly full and complete. In an address such as had been delivered, and which touched upon so many topics, it was difficult to please everybody. A good deal had been said about Lloyd's, but Lloyd's was not the only institution which had got to do with the building and classification of ships. He did not see why the other registries should be altogether ignored. The remarks as to the library and reading room were slightly misleading. He said they were "completed." They certainly possessed a reading room and library, but so long as books were being published their Library Committee would have to go on increasing the collection, replacing obsolete books with those of recent date, so that their library would demand a continuous although possibly somewhat reduced expenditure. The more technical and specialised these productions became the more were books required. He would like to say a word about the reduction of scantlings in shipbuilding. There seemed a good deal of backing and filling in that respect, and they found the registry which suggested the idea that 20 per cent. was coming off the steel vessels now beautifully whittling away. They were rapidly approaching the same hull weight in the steel as in the old iron ships. It would have been far more to the purpose with such a partially concealed dislike and fear of steel to have frankly admitted that the step taken had been too great, and to have at once lessened the nominal reduction. This he considered would have been more manly than bolstering it up with side issues. He quite admitted that the reduction made, say in the side plating, especially in small coasting vessels, which were knocked a good deal about, rubbing along barges and such like, was certainly too great, they became in time uncommonly like an old tin-pan. The plates may have been strong enough for the work, but they were not strong enough for this exceptional work. These vessels should be built thicker to stand

the local damage sustained. He was very much inclined to doubt the assertion made regarding Norwegian ships hanging out for thirty years compared with the twenty-six years of the British vessel. The paper alluded to might say so; but he should like to see the proof of it before he believed it. What he had seen of them did not invariably commend themselves to him as the brightest specimens of naval architecture, and more especially the wooden sailing vessels. These vessels were often seen decorated with windmills to drive the pumps, which in itself looked somewhat suspicious. How they attained this long life was a mystery to him. The progressive load trials had been alluded to, and only recently he had pressed very hard to obtain the progressive trials of a steamer. The conditions of weather, etc., were very favourable, but he was told by the owners they had had several progressive trials from which they experienced not the slightest benefit, and so they were not inclined to take any further trouble in the matter. They were told in the President's address it "amply repaid them to immerse the vessel," and so on; but when they got this thrown at them it was rather a staggerer. The owners he referred to were not of that class to whom the appellation "stick-in-the-mud" could be used, they acted from their experience of several loaded trials; but, whether these progressive trials were conducted as they ought to have been, and classified and deductions drawn from them, he was unable to say; he only stated and emphasized the fact. In making progressive trials the aim was not only to get the success of the trials, but also the defects, which were sometimes more instructive than the successes. If a good full speed run was made a number of people thought that all was right, and the general inclination then was to make for the haven as soon as possible. The slower trials, however, might be of infinitely more benefit than the faster ones. He certainly believed they should get some tangible benefit out of the graduated trials, otherwise the expense and trouble would be reckoned as so much loss. The President said "it would" supply definite information—he begged to suggest that "it should" supply useful and often much needed information. Perhaps it would be well to suggest that in speaking of the coefficient of fineness the figures referred to vessels of fair size, as those quoted were more prejudicial in small vessels—not so disadvantageous to the large ones. On the whole, the tonnage basis had altered considerably lately. They had had the 1854 Act, and several amendments on it, then there was the "Isabella" arrangement coming into force and upsetting the tonnage basis, which he understood would be disestablished shortly; but he had not heard yet of a vessel adjusted on the "Isabella" system.

There was a considerable number of vessels going under the "Isabella" tonnage. Some of those vessels got 100 to 150 tons, making a very considerable difference in the tonnage. Taking the tonnage found on the register books was apt to mislead, and might, if adjusted on the same basis, make a perceptible difference in the coefficients. Perhaps he ought to apologise for venturing to draw attention to these portions of the address which he was more anxious to elucidate than criticise. He had very much pleasure in moving a vote of thanks to their President for his very excellent address, and hoped he would have plenty of strength and energy to be their leader and figure-head for the ensuing season.

Mr. WIGHAM RICHARDSON had great pleasure in seconding the motion of Mr. Macoll. He should like to explain that this duty should have fallen to Mr. Doxford, who had come, at great inconvenience, to the meeting, but was suffering so much from hoarseness that he believed if he tried to address them they would not be able to hear him. He hoped, when next they had the pleasure of seeing him there, he might be completely restored to health. With that introduction he should like to speak very warmly in seconding the vote of thanks which Mr. Macoll had proposed. He thought this an extremely weighty address, and it would be a very long time before they heard the last of it. He thought for years to come they would find the tables and figures and remarks of their President quoted and discussed. What Mr. Macoll said about different registries was hardly fair to their President. Their President had been appointed by the Institution to be one of the members of Lloyd's Committee, and as such he had an inner knowledge with regard to Lloyd's which none of them had, and he had imparted opinions to them founded on that knowledge. It had been to himself matter of very great satisfaction that that sub-committee had been appointed, and that this Institution had to nominate one-third of the committee. He thought if similar steps had been taken, as so often urged, a quarter of a century ago, it would have been better for all of them, and much greater progress would have been made. Now, let them acknowledge the encouraging signs of these present times, and he hoped in the hands of their President and his colleagues, Lloyd's would make up a great deal of the backway, and so strengthen and cement their many relationships.

Professor WEIGHTON, M.A., said it gave him great pleasure to support the motion, and in doing so, without in the least criticising the President's address, which, whilst Mr. Macoll was at it, struck him as rather an irregular proceeding, still he should like to call attention to something

the President had said which had a personal interest for him (Prof. Weighton). He referred to the paragraph in the address which went to show that the President had excited the curiosity and stimulated the interest of certain of his subordinates to such an extent that they were going to read a paper on "Types and Proportions of Mercantile Steamers, in relation to Cost, carrying Capacity, and Speed." Now, the point he should like to specially emphasize, having regard to the professional progress of the younger members of the Institution, was this, that it said a great deal for Mr. Thompson that he allowed his subordinates to have access to such very important information. He thought if all the gentlemen, who were in positions akin to that of Mr. Thompson, were to treat those under them in a similar way there would be no fear of the future of engineering and shipbuilding in this district or in any other district.

Mr. JOHN GRAVELL said there was one matter mentioned in the President's address to which he wished to call their attention. They had been kind enough, through their Council, to nominate him as their representative on the Council of the Durham College of Science, and in his connection with that Council he had learned that if Prof. Weighton was to have really fair-play, and scope for his educational work, certain things were necessary for the better training of his students. Prof. Weighton had now for one year filled the chair of Engineering and Naval Architecture in the College, and so far his efforts had been satisfactory. He had been elected to the chair through the recommendation of this Institution, and therefore it became the duty of the members of the Institution to do all in their power to give him their cordial and hearty support. He had hoped that Prof. Weighton would in his remarks have mentioned some of the appliances he wished to obtain for the use of his students; he was sorry he had not done so, perhaps he was too bashful. But he (Mr. Gravell) was not going to be too bashful; he would say at once that so far as marine engineering was concerned, for the better training of the students in this department, Prof. Weighton would be glad to have a quadruple expansion engine fitted up in the precincts of the College, so that with the technical a little practical knowledge might also be given. The obtaining of such an adjunct to the College in a district like this should not be a difficult matter. Many of the engineering and shipbuilding firms in the district had kindly come forward to assist in raising the stipend of the Professor, for which the Institution must feel very grateful. But he was of opinion that if these firms would still further assist in the direction he had pointed out it would not only

be a very laudable act, but doubtless they would reap a benefit in return from the better education of those youths they employed who attended the College lectures. He begged to support the vote of thanks to the President for his interesting and suggestive address.

Principal GARNETT, M.A., D.C.L., said he had been asked to support the vote of thanks to the President. Personally, and in the name of the College Council, he had to thank the President of this Institution, as he had had to thank many Past-Presidents, for the exceedingly kind remarks which he had introduced into the Presidential Address in regard to the College. He was sure he might also ask them to express their heartiest thanks to him for the whole of the paper which he had read that night. He might say a word or two respecting the passages in that address in which the Durham College of Science had been mentioned. First of all he ought to express the extreme satisfaction which he had felt—and the Council of the College had felt—at the first, should he say experimental, year's work with Professor Weighton. He thought no department of the College had ever been started under such exceedingly favourable auspices as the Engineering Department last year. In the Engineering and Agricultural Departments they had had every reason to congratulate themselves upon the success they had had, and particularly upon the professors who had been appointed. In the former case they were indebted to this Institution, as the members knew, not only for the means whereby their Professor was maintained, but for the possession of such an exceedingly able Professor himself. Then with respect to the experimental engine. In the course of a few weeks he hoped to have the satisfaction of inviting the members of that Institution to witness the laying of the foundation stone of a new portion of the building, and he thought they would agree with him that in some respects they were acting wisely in deferring this ceremony, inasmuch as it would be laid when the Engineering Department had reached the height of the first floor. Under these circumstances they would be able to form an idea of what that department was to be, and see the corner set apart for the experimental engine which had been talked about. He must not betray a secret, but they did hope to have a very distinguished personage to open that Department, and it was most important when he came—if he did come—that the George Stephenson Laboratory should be equipped in a manner to do honour to its opener. They had just one year to have this experimental laboratory equipped. There should be no difficulty in providing a set of engines. He could not imagine such a difficulty exist-

ing in such a district as this so full of successful engineers, and where marine engineering was so important and staple a manufacture. A word about the experimental tank. This was not quite such an easy matter to deal with as the experimental engine, simply because it occupied a good deal more ground. He had the pleasure a little while ago of spending some hours with Mr. Froude at the experimental tank of the Admiralty, in the gunboat yard at Haslar. He learned a good deal about the experiments carried on and the appliances necessary for their conduct. It was not such an easy matter as the engine, he had said, but the difficulties in the way were by no means insuperable. What site might be most suitable for such a tank was for the Council of the North-East Coast Institution to say, and it might be found that with smaller models one-half the dimensions of the experimental tank at Haslar, which was about 400 feet long, 20 feet broad, and 10 feet deep, would suffice for to get rid of the effect of the reflected waves upon the models. It might then be possible to obtain equally accurate results with very delicate machinery, dynamometers, and electric motors, and there should not then be any difficulty with respect to site, or expense, or detail. He hoped the members of the Institution would honour the College with their presence when the day was fixed for laying the foundation stone of the George Stephenson Engineering Department.

Mr. MACOLL put the motion to the meeting, and it was carried by acclamation.

MR. THOMPSON'S REPLY.

The PRESIDENT thanked the members heartily for the vote of thanks. He did not expect that anyone could discuss the tables that night, but he hoped they would investigate them, and that papers might be read before the Institution based upon the information he had supplied. It was his wish that the Institution should to the fullest extent profit by what he had put before them. The tables as given were accurate. The gross tonnage, as they knew, was of no use; but the deadweight and the weight of material were correct, and should be found useful. With respect to Mr. Macoll's remarks in regard to the library, what he (the President) meant was that they had secured "a place of habitation." He did not by any means think that the library was complete, though it contained some very valuable books, and Mr. Macoll or any other gentleman was quite at liberty to further assist them in adding to their

stock of books, and it was needless to say the more they gave the better they would appreciate the donors. Regarding the lives of vessels, the figures he had given were taken from a periodical which fell into his hands while reading up for the address. Referring to the reduction of scantling allowed by Lloyd's for vessels built of steel, he had to say that where the owner of a ship built ten years ago obtained a reduction of 20 per cent. off the iron scantling, he would now only receive about 10 per cent. for a vessel built at the present time; still both vessels would be classed alike, although they were not equal, hence Lloyd's 100 A1 class was evidently of a varying commercial value, and this was not a pleasant thing for owners to have to look at. Mr. Macoll suggested in reference to the remarks on progressive speed trials that the word "should" ought to be used in place of "would," he did not care which it was if they would only "do." If the progressive trials were systematically carried out it would be a great benefit during the life of a ship, even though it incurred the loss of a few days at the commencement of her career. He had to thank Mr. Richardson for his remarks in regard to Lloyd's Sub-Committee for Surveyors getting now into work. They had a number of proposals to discuss at their next meeting, which would, no doubt, last into the second day, or be referred back for further consideration. They ought to do some good and bring about an uniform practice. Referring to the remarks made by Principal Garnett, he (the President) had thrown out the hints alluded to, because since his earlier days he had always been interested in technical education. He had felt the want of it himself, and had to work hard to gain the position he had secured; and he would be glad to assist as far as lay in his power anyone wishful to acquire or increase their technical knowledge. He agreed with Principal Garnett that in endeavouring to carry out any of the suggestions he had made in his address for the furtherance of these ends they must expect to meet with difficulties; but surely this district was wealthy enough to provide the necessary funds, and capable of surmounting such difficulties. This Institution had acquired some influence in the district, and an appeal might be made to the various public bodies who had money placed at their disposal by the new Act. He thanked them for their attention, and was sure that the tables he had put before them would be useful, and that something more might be learnt from a close investigation of them.

The meeting then dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

NINTH SESSION, 1892-93.

PROCEEDINGS.

SECOND GENERAL MEETING OF THE SESSION, HELD IN THE ATHENÆUM, WEST HARTLEPOOL, ON SATURDAY EVENING, NOVEMBER 12TH, 1892.

ROBERT THOMPSON, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on October 10th, which were approved by the members present and signed by the President.

The PRESIDENT took occasion to remark upon the pleasure he had in being there for the first time as chairman. He had always been gratified with the interest taken by the Hartlepool members in the Institution, and by their contributions of valuable papers, also by their donations to the Medal Fund.

The ballot for new members having been taken, the President appointed Mr. T. Mudd and Mr. H. Withy to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Joseph Armstrong, Ship Draughtsman, 27, Ripon Street, Sunderland.
Angus Cameron, Foreman Shipwright, c/o James Laing, Esq., Deptford Yard, Sunderland.
James Carver Clark, Engineer, 5, Rium Terrace, West Hartlepool.
Robert Craig, Supt. Engineer, 13, Milton Street, West Hartlepool.
Robert M. Ferrier, B.Sc., Engineer, Durham College of Science, Barras Bridge, Newcastle-on-Tyne.

Charles Fowling, Ship Surveyor, Lloyd's Register of Shipping, Dock Office Buildings, West Hartlepool.

Felix de Kodolitsch, Engineer, Arsenale del Lloyd Austriaco, Trieste.

Giacomo Luigi Petrini, C.E., Naval Architect, c/o Messrs. Gio Ansaldo & Co., Sestri-Ponente, Italy.

Leon Vivet, Naval Architect, Bureau Veritas, 12, Rue de Seine, Paris.

James Edmund Wilson, Ship Draughtsman, 58, Forster Street, Sunderland, M.

MEMBERS (LATE GRADUATES).

Walter Blackett, Engineer, 60, Marine Parade, Sheerness.

William Forster Hindson, Engineering Draughtsman, 7, Elysium Lane, Bensham, Gateshead-on-Tyne.

Swinton Stoddart, Ship Draughtsman, 24, North Milburn Street, Sunderland.

Herbert Jas. Weinberg, Engineer, 14, Guillaume Terrace, Southampton.

Alfred Westmacott, Engineer, Benwell Hill, Newcastle-on-Tyne.

Henry B. Wortley, Ship Draughtsman, 73, Chillingham Road, Heaton, Newcastle-upon-Tyne.

ASSOCIATES.

John George Jordan, Accountant, 24, Stansfield Street, Sunderland.

John Finley Runcieman, Marine Superintendent, Harton, South Shields.

GRADUATES.

Ernest Baker, Apprentice Engineer, c/o Messrs. The Wallsend Slipway and Engineering Co., Wallsend-on-Tyne.

Edmund Ligertwood, Apprentice Engineer, 25, Victoria Street, Newcastle-on-Tyne.

John Robert Reid, Apprentice Engineer, 25, Derwent Street, Sunderland, B.

Ernest Vivian Wilkin, Apprentice Engineer, 22, Victoria Street, Newcastle-on-Tyne.

Mr. J. R. Fothergill read a paper on the "Combustion of Coal and Prevention of Smoke."

Mr. J. Denholm Young read a paper "On a System of Mechanical Aid to the Investigation of Speed Curves."

COMBUSTION OF COAL AND PREVENTION OF SMOKE.

By J. R. FOTHERGILL, Vice-President.

[Read before the Institution, in West Hartlepool, on Saturday, November 12th, 1892.]

This subject is one that has had the attention of all manner of men. Some have accomplished considerable success, but the great majority appear to have done little or no good. Writers generally to journals, periodicals, and the press revel in schemes and devices and patent and re-patent mechanical contrivances to complete combustion and prevent smoke, that one might imagine the prevention of smoke was a matter of the greatest simplicity, were it not that dense volumes rolling from lofty chimneys scatter far and wide showers of smut, leaving tangible evidence of practical difficulties to be overcome, or a selfish indifference on the part of the consumer to the consideration of his fellow-man.

It is possibly within the knowledge of this Institution that the Mayor of Newcastle convened a meeting, which was held in the Town Hall, Newcastle, on the 4th December, 1890, to discuss this subject. So far as the writer is aware nothing material or of importance resulted from that meeting. The fact that such a meeting was convened must necessarily impress the community at large, as well as manufacturers and users of coal generally, that the prevention of smoke is of considerable importance, a matter in which the public are seriously interested, and year by year less likely to tolerate. In fact in many of the larger towns repressive measures are being enforced with reported fair success.

Some of them might have noticed a complete absence of smoke during the first few months' working of a new factory or mill, but as time progresses a tingy cloud appears, which in a few additional months develops into "full-grown" smoke, rolling forth in exuberant profusion, the undoubted admiration of the fireman who is satisfied "steam is up."

The neighbours protest. The proprietor emphatically asserts if he is interfered with he will be obliged to close his factory from lack of profit, and unfortunately there are still some of the old school of medical official inspectors who fail to realise the deleterious effect of smoke, and so the baneful nuisance grows apace.

The writer is fully aware that in the larger towns the dense "pea-soup" fogs are in a great measure due to the ordinary domestic range or open fire, but so long as the public will have the open hearth they must be content to have some of the smoke, and thus he does not propose to refer to this side of the question.

In this nineteenth century—an age so noted for its marvellous scientific and practical achievements in all engineering subjects—does it not seem incredible that we are content to accept the smoke nuisance as inevitable, a sort of necessary evil inseparable to the combustion of coal?

What is smoke? Can it be prevented? If it can be prevented, why is it tolerated? These are the questions the writer desires to put before the members of this Institution for discussion.

In venturing to put to the meeting these questions for discussion the writer is encouraged by the belief that the members of this Institution, by their scientific attainments and practical pursuits, are well qualified to consider this question, and express opinions which will have weight with the public, and clear away the fog of mystery in which this subject is supposed to be involved.

The writer assumes that at many of the works with which members are associated various expedients and apparatus have from time to time been tried, and he hopes this paper may be the means of making public the results of such experiments, and so guide others in their endeavour to abate the smoke nuisance.

It is not the writer's intention to propound a new theory, or to do other than consider the practical application of the principles of combustion to the prevention of smoke in the consuming of coal in steam boilers generally. To enter fully into the theory and chemistry of combustion is not by any means his intention, nor if it were possible to do so within the limits of an Institution paper is it desirable, yet that the paper may be clearly defined and fairly considered it is essential to somewhat touch upon the elementary side of the question.

For convenience of reference and to facilitate discussion the writer has added in the form of an Appendix tables and data giving the constituents of coal, coal gas, air, etc. (See page 52 *et seq.*)

By reference to Table IV. it will be seen North-country coal contains a larger percentage of hydrogen than Welsh. A coal containing hydrogen in combination with carbon forming bitumen—tar—is essentially a smoke-producing coal, and the richer or more bituminous the greater the smoke-producing capability. It is due to the bituminous quality of North-country coal that it produces more smoke than Welsh. Certainly the best Welsh coals are smokeless, but that cannot be said of all Welsh coals, although their power of producing smoke is not equal to North-country.

The analysis of coal, as given in Table IV., is in the usual form; although this form is of great value in many respects, it does not enable the engineer to estimate the smoke-producing quality. In addition to such analysis should be given the percentage of fixed and volatilised carbon, as per Table V., that some estimate can be formed as to its bituminous character.

In the general acceptance of the term, all the products of combustion which are seen issuing from a chimney is called smoke. Although this is the common expression it is far from scientifically correct. True smoke is the unconsumed carbon liberated from the hydrocarbons. There is also an additional cause suggested by M. Scheurer-Kestner, that the gases of combustion are dissociated at very high temperatures, and if the dissociated gases are suddenly cooled carbon is precipitated and smoke produced. This theory, although probably correct, in reverberatory furnaces does not appear to be possible in the ordinary boiler furnace. The nominal temperature of the complete combustion of coal of average composition is about 5,000 degs. Fah., whereas the average temperature of the gases at the surface of a clear fire in an ordinary furnace rarely exceeds 2,000 degs. Fah., which is not sufficient to produce dissociation of the gases, and again, even if dissociation took place it is almost certain as the gases cooled they would immediately recombine. Therefore, further consideration of this theory to the present paper does not appear necessary.

When a furnace in an active condition is fired the fresh coal thrown on at once absorbs heat from the fire and disengages the bituminous constituents by volatilisation, or, in other words, generates the gaseous portion of the coal by distillation. Until this process is completed the fixed carbon or coke is not consumed. Volatilisation is the most cooling process in nature, due to the quantity of heat which is directly converted from the sensible to the latent state.

Throwing fresh coal on a fire materially reduces the furnace temperature, and thus it is most essential to avoid heavy firing.

The only constituents of the gaseous portion of the coal volatilised by the first application of heat which need have our consideration are hydrogen and carbon in chemical combination as a hydrocarbon vapour or gas.

As these gases generate, the hydrogen having a great affinity for oxygen readily unites with the oxygen of the air supplied to the furnace to the production of water—steam. The carbon thus liberated if it cannot find and unite with its necessary proportion of oxygen passes away unconsumed, forming dense clouds of smoke. When the necessary quantity of air is supplied, and in such manner that its oxygen will combine with the carbon to complete combustion, carbonic acid is formed and smoke prevented.

We thus arrive at this fact: The essential requisite necessary to prevent smoke is the supplying of oxygen in such quantity, and in such manner, as will readily combine with the liberated carbon from the hydrocarbon gases to the production of carbonic acid.

At first sight this would appear to be no difficult matter, but a careful consideration of the whole question shows that no hap-hazard system of air supply can be successful. The air supply must be governed by scientific principles, and although practical difficulties prevent the complete fulfilment of a theoretical application of air to the furnace, yet much can be done and considerable success achieved by judicious arrangement.

Scientifically we know definite quantities of air are required for the chemical combustion of coal (see Tables II. and III.), but practical experience, as well as chemical investigation, shows that under the ordinary furnace conditions it is necessary to supply double the amount chemically required.

In the laboratory, where all the conditions are most suitable, the chemist finds, not only is time an indispensable requirement, but an excess of oxygen must be supplied, so that the carbon may be saturated in a bath of oxygen to complete the chemical union of the carbon and oxygen to carbonic acid, and similarly with the hydrogen and oxygen to steam, although the excess of oxygen required is, in this case, less, as the affinity of hydrogen for oxygen is greater than that of carbon, even to the detriment of the carbon. Although it is essential that a large excess of air be supplied in excess of that theoretically required, yet it must not be forgotten that for every cubic foot of oxygen supplied 3·76 cubic feet of nitrogen are supplied, which takes no part in combustion, but abstracts heat from the furnace, lowering the temperature of the gases. The excess

of nitrogen also conduces to further evil, in that it, by its large volume, interposes between the atoms of carbon and oxygen, preventing their union and combustion.

There is also another important consideration which has a material consequence on the union of these gases and that is the temperature at which they combine. Hydrogen unites with oxygen at not less than about 600 degs. Fah., and carbon unites with oxygen at not less than about 800 degs. Fah. The higher they exceed these temperatures within certain limits the more readily they unite and the less surplus oxygen required. On the other hand, if the hydrocarbon gases, as they generate, are allowed to cool below these temperatures they will not unite with the oxygen, and thus they pass away unconsumed, forming dense volumes of smoke.

By reference to Table VI. we note that practically the same quantity of air is required for the combustion of Welsh coal as for Newcastle, but we also observe very different quantities are required for the fixed carbon or coke and for the volatilised matter. Suppose no other arrangement is made for the air supply to the furnace than by the ash-pit, which is not by any means an uncommon practice, what is the effect? Say a furnace, 3 feet diameter; firebars, 5 feet 6 inches long, and 1 inch thick or broad at the top; the openings between the bars, 5 feet by ½ inch. There would be 24 bars to a furnace, the total openings between the bars would equal 5 square feet. The area of opening to the ash-pit, assuming the top of the deadplate to be in a line with the centre of the furnace and allowing for thickness of deadplate, etc., would be, say 3 square feet. Take the consumption at 15 lbs. per square foot of grate per hour, which is not by any means heavy, we find that, with 300 cubic feet of air per pound of coal (see Table VI.), we require a column of air 3 square feet in sectional area and 24,750 feet in length, sent into the ash-pit per hour, moving with a velocity of 4·68 miles per hour, requiring a funnel temperature of, say 500 degs. Fah., giving a water-gauge funnel draught of ¼ to ⅜ of an inch, always assuming the fire is clean and free from clinker.

We shall endeavour to show how difficult, nay, how practically impossible it is, to fulfil the required conditions of air admission to the gases by the ash-pit and through the fire only, and more particularly as the fires become dirty and the bars clinkered.

Air admitted at the ash-pit comes in contact with the hot body of coke on the firebars, producing carbonic acid with great heat, which, as it passes up through the burning coal takes up another equivalent of carbon with the reduction of carbonic acid to carbonic oxide. If the

carbonic oxide so formed cannot find and take up another equivalent of oxygen it passes away unconsumed with great loss of heat, although carbon may be consumed to carbonic oxide without smoke.

The most serious objection to the endeavour to supply the whole of the air at the ash-pit is to be found in the explanation the writer has given of what takes place when fresh coal is thrown on the fire. The volatile matter, nearly 35 per cent. in Newcastle coal (see Table V.), is liberated on the first application of heat, and must pass away before the coke is consumed. For the combustion of this matter 36 per cent. of the whole air supply is required (see Table VI.). Do we not at once see how absolutely impossible it is to supply this large quantity of air at the grate and through the fire? The air for the combustion of the gases must be supplied to the gases direct, so that free oxygen in sufficient quantity is brought in direct contact with the hydrocarbon gases as they are generated and before they have time to cool, otherwise smoke must be produced.

Since Parkes, in 1820, took out the first patent for admitting air at the bridge by the system known as the "split bridge," patents innumerable have been taken out by which air is admitted at the front of the bridge, at the back, at the top, underneath, through, and in fact at every conceivable position.

To attempt to describe one-twentieth of the devices for admitting air either at the bridge or in the neighbourhood of the bridge, would in itself compile a pretty big work, and must even at the present day be a source of considerable revenue to the Patent Office.

We now approach what may be considered the most involved and perplexed problem of the whole question. Perplexed and involved in that so many devices and schemes have been designed as to how and where the air should be admitted. Each scheme having its supporters and opponents frequently carried away by infatuated enthusiasm that the truth is oft involved in imagination.

The first great consideration is that theoretically the air supply to the gases should decrease as the hydrocarbon gases are consumed and pass away, then cease until fresh coal is again thrown on the fire. Any device to govern the air admission must be automatic in its operation to successfully achieve this result, and as yet, although many arrangements have been tried, the writer is not aware that practical success has been achieved, and this is not at all surprising when the practical difficulties to be overcome are fully realised.

Admitting air at the bridge or in the neighbourhood of the bridge

undoubtedly will materially reduce the production of smoke, but unfortunately, although such arrangements are of great value when carefully designed and newly fitted, yet practical difficulties overcome their utility, and they soon fall into disuse or are altogether removed.

The writer has had considerable experience in the admission of air under various conditions at the bridge, and his experience is that the air admission holes get filled up with ash and cinder, or the whole efficiency of the arrangement is impaired by the bridge, whether constructed of firebrick, or of cast iron and firebrick, being soon burnt out and disarranged, thus admitting enormous volumes of air to the furnace, chilling the gases, carrying off the heat, and materially lowering the steaming efficiency of the boiler. It is not at all uncommon to find when air is admitted under or at the back of the bridge a second fire behind the bridge, due to the indifference and carelessness of stokers, forcing with the firing tools, partially burnt coal and cinder over the bridge and neglecting to remove them. The writer has seen bridges burnt down from this cause.

Time can not, or will not, be given to the constant repairing and keeping in order of special arrangements, and frequently due to complete ignorance of the principle of the arrangement and the indifference of the consumer, or want of direct responsibility, the whole arrangement is condemned and pulled out. This to a very great extent explains why it is we so often find when a new mill or factory is built or an old boiler replaced by a new one, there is for a time an almost complete absence of smoke, then as the arrangement burns out smoke is gradnally produced, increasing in volume with the inevitable result, a continuous black cloud.

In the admission of air to the gases too much stress cannot be laid on the absolute necessity to break up the air as it enters the furnace into small streams or thin films. Air supplied in volume chills and lowers the temperature of the gases. Union of the carbon and oxygen is prevented and smoke produced. Breaking up the air into small jets by admission through ½ inch holes, or into a thin film through narrow slits, allows the air to penetrate and mingle with the gases to combination and complete combustion. In fact the small jets of air entering with velocity act as so many air pokers, and thoroughly stirs up the gases to the very best advantage to the union of the oxygen with the hydrocarbons.

Perhaps the most practical and successful arrangement for the admission of air to the gases direct is by perforated baffles at the furnace front. It has been shown over and over again by trials conducted by fully recognised authorities (see Table VIII.)* that smoke can be practically prevented by a judicious admission of air at the furnace front,

* Page 54.

but the baffles must be perforated with a sufficient number of ½ inch holes, and free admission made for a regulated quantity of air to the baffles. The holes should be spaced further apart and somewhat smaller in diameter towards the top of the furnace, as there is a possibility of the air passing along the furnace crown and chilling it.

The want of a reliable automatic apparatus to regulate the admission of air to the gases necessitates a compromise as to the quantity supplied, and it is due to this circumstance the absolute and entire prevention of smoke is rendered so difficult, nay almost impossible, yet there is no question whatever, but that a carefully designed arrangement for the admission of air at the furnace front, or at the bridge, or partially at both, will practically reduce the production of smoke to the smallest possible quantity, a mere discoloration of the escaping gases when fresh coal is thrown on the fire.

The great danger to guard against in the admission of air to the gases is in supplying a very much larger quantity than is necessary. An excess of air lowers the furnace temperature, and although smoke may be prevented, steam cannot be maintained. The supply of air must in a large measure depend upon the coal used, but perhaps the greatest trouble is in the manipulation of the fires. If the fires are allowed to burn into holes, or the fresh coal supplied be thrown on in a heap, and practically no fire in the corners against the bridge—a very common fault, particularly when using long grates—a very large excess of air flows in from the ash-pit where the grate is bare at the bridge. Under such conditions the air enters the furnace in volume, chills the gases, produces smoke, and reduces the steam. If in addition to this air is admitted at the bridge or furnace front, or at both, the evil is increased, therefore by closing the air admission to these parts the steaming somewhat improves, and thus without further consideration it is concluded the arrangement for air admission to the gases is a mistaken and foolish idea and thus condemned and taken out, whereas with proper firing, in which the fires are kept at a uniform thickness, the quantity of air admitted at the grate to the furnace becomes a regular quantity, and therefore the quantity to the gases can be regulated.

No possible arrangement of air supply, however scientifically considered, can be successful where ignorance and prejudice are displayed in the stoking. It is impossible to be too emphatic on this point, more particularly as owners and managers, generally, of mills and factories are in the hands of their stoker, who is frequently designated "their engineer," and accept without hesitation his views and ignorant prejudices.

Probably some form of mechanical stoker will, in time, prove the best solution of the present stoking difficulty. The mechanical stoker avoids the necessity of continually opening fire-doors, a most important advantage in the prevention of smoke.

The writer is of the opinion there is no excuse whatever for the dense volumes of smoke so often seen issuing from the chimneys of mills and factories, and he believes if the Public Health Act was impartially and firmly administered this unnecessary nuisance would soon be a thing of the past.

Although the writer feels he has left very much unsaid, in fact, that he has only touched the fringe of this most important subject, yet he hopes sufficient material will be found to promote useful discussion.

In conclusion, he would venture to suggest to some of the many members of this Institution who are at the head of important engineering works to carry out a few simple experiments, which must necessarily be to their own advantage, and give the public the benefit of their experience, and thus sustain the reputation of the Institution as a body whose primary object is scientific investigation and the development of practical engineering.

Summary.

Causes which Produce Smoke.

1.—Want of trained, intelligent stokers.

2.—Heavy firing at long intervals by which the hydrocarbons are volatilised at low temperatures and cannot combine with oxygen.

3.—No provision for admission of air to the gases except through the fire.

4.—Not keeping in thorough order any arrangement for the admission of air to the gases, whereby, either a large excess is admitted to the furnace in volume, or the admission may be partially or wholly prevented.

5.—Not understanding the principle of admission of air to the gases, whereby, tested and proved arrangements for want of keeping in thorough order and repair are condemned and removed.

6.—Working boilers to twice their designed power. A very prevalent cause.

7.—Inordinate long grates and forcing the fires by constant use of fire-tools, by which the fires are burnt into holes and large volumes of air admitted at irregular intervals.

8.—To the majority of those in charge, so long as there is plenty of steam, the production of smoke appears inevitable, and little or no consideration is given to the subject.

Deductions.

1.—Regular, Even, Constant, and Light Stoking.

The firing should be constant and regular, and the coals thrown evenly and thinly over the hot coke, so that the volatilised gases, as they generate from the fresh coal, may be rapidly heated, facilitating their ready union with oxygen.

2.—Special Attention in Preventing Fires Burning Unevenly and into Holes, particularly at the Bridge Corners.

It is imperative to keep the grate evenly covered at a regular thickness, otherwise the admission of air must be most irregular and in very varying quantities, making any arrangement for regulating the air admission, particularly to the gases, utterly useless.

3.—Provision for Air Supply to the Gases Direct.

The air can be supplied either at the furnace front or at the bridge, or partially at both places, but on no consideration must the air be supplied in volume.

4.—Owner or Manager made Responsible for the Production of Smoke.

5.—Impartial and Firm Administration of the Public Health Act, 1875, for the Prevention of Smoke.

APPENDIX A.

TABLE I.

Gases.	Symbols.
Carbonic acid	CO_2
Carbonic oxide	CO
Water—steam	H_2O
Sulphurous acid	SO_2

100 parts atmospheric air = 77 N + 23 O.

Hydrocarbon vapours or gases are distilled from the bituminous portion of the coal in various combinations of hydrogen and carbon depending upon the temperature.

TABLE II.

One Pound.	Air Consumed at 62° Fah.	Produces.
Hydrogen	34·8 lbs., or 457 cubic ft.	Water—steam.
Carbon, completely burned ...	11·6 „ „ 152 „ „	Carbonic acid.
„ partially „ ...	5·8 „ „ 76 „ „	„ oxide.
Sulphur	4·3 „ „ 57 „ „	Sulphurous acid.

TABLE III.

To find the quantity of air at 62° Fah., under one atmosphere, chemically consumed in the complete combustion of 1 lb. of coal of a given composition :—

A = Air, C = Carbon, H = Hydrogen, O = Oxygen.

$$A = 1{\cdot}52\,(C + 3,\ H - {\cdot}4,\ O).$$

N.B.—Sulphur, which usually is an insignificant quantity, is omitted for the sake of simplicity.

TABLE IV.

AVERAGE ANALYSIS OF MANY SAMPLES, BY MESSRS. DELABECHE AND PLAYFAIR.

Coals.	Specific Gravity.	Composition (Percentage).					
		Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.
Welsh ...	1·315	83·78	4·79	0·98	1·43	4·15	4·91
Newcastle ...	1·256	82·12	5·31	1·35	1·24	5·69	3·77

TABLE V.

Coals (same as Table IV.).	Fixed Carbon (Coke).	Volatilised Carbon.	Total Volatile Matter.	Ash.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Welsh	73	10·78	22·13	4·91
Newcastle ...	61	21·12	34·71	3·77

TABLE VI.

Applying rule, Table III., to the analysis given in Tables IV. and V., the air required, in round figures, per lb. of coal is as follows :—

	Cubic Feet.
Welsh	146
Newcastle	145

	Welsh.		Newcastle.	
	Cubic Feet.	Per Cent.	Cubic Feet.	Per Cent.
For the fixed portion ...	111 ...	76 ...	92 ...	63
For the volatilised portion	35 ...	24 ...	53 ...	36

In practice, reliable trials show it is necessary to supply double this quantity. From 280 to 300 cubic feet per lb. of coal should be taken in practical calculations.

TABLE VII.

In round figures, the combustion of 1 lb. of coal by 800 cubic feet of air produces 550 cubic feet of gas when issuing from the chimney at a temperature of 500 degs. Fah.

The combustion of 1 ton of coal produces about 1¼ million cubic feet of gas at 500 degs. Fah.

The combustion of 1 ton of coal produces nearly ½ ton of water.

TABLE VIII.

Some notable systematic trials by recognised authorities :—

W. H. Houldsworth, at Manchester, 1842-43.

Longridge, Armstrong, & Richardson, at Newcastle, 1857—
For the Steam Collieries' Association.

Miller & Taplin, at Newcastle, 1858—
For the Admiralty.

Taplin, Lynn, & Dobson, at Cardiff, 1858—
For the South Wales Collieries' Association.

T. W. Miller, Keyham Factory, Dockyard, Devonport, 1864—
For the Admiralty.

Richardson & Fletcher, at Wigan, 1866-68—
For the South Lancashire and Cheshire Coal Association.

Nicoll & Lynn, at Wigan, 1867—
For the Admiralty.

D. K. Clark, South Kensington and Manchester Exhibitions, 1881-82—
For the Smoke Abatement Committee.

APPENDIX B.

Explanation of the Drawings.

To have embodied in the paper a complete explanation of the drawings would have unnecessarily prolonged it to an inconvenient length, thus the reason of their being added as an Appendix.

The writer has not added these drawings solely to show how air can be admitted to the gases, but, with the exception of the last two, as an illustration of the earliest successful patents for the prevention of smoke by the admission of air to the gases.

Shoals of patents have been taken out, but in the majority of instances, they are either a perversion of the historic split bridge of Parkes, or some modification or combination of the first half-dozen patents referred to by the drawings.

These patents cover the admission of air at the furnace front, at the top, front, and back of the bridge, heating it and breaking it up into streams.

The constant re-patenting of these old ideas must be a source of considerable revenue to the Patent Office, yet there are many who think the moral rectitude of that office would be improved if they more freely exercised the discretionary power granted them.

PLATE No. III.—Robertson's patent, No. 2,437, 1800.—This is the first patent for admission of air at the front of the furnace to the top of the fire. Air is admitted by a narrow passage B, having about the same breadth as the fire, and situated immediately above the hopper by which the coal is supplied to the furnace.

PLATE No. IV.—Parkes's patent, No. 4,455, 1820.—Parkes was the first to take out a patent for admission of air at the bridge by the arrangement commonly known as the "historic split bridge." This arrangement of bridge, in one form or another, has been patented over and over again. Air is admitted from the ash-pit by a regulating valve A, Fig. 1, and through a narrow passage to the contracted opening at the top of the bridge B to the gases. Fig. 2 illustrates the application of Parkes's bridge to a marine boiler.

PLATE No. V.—Wakefield's patent, No. 4,472, 1820.—Wakefield commenced his experiments for the prevention of smoke some three or four years earlier than Parkes, but Parkes took out a patent first. The important difference in these patents is that Parkes admitted air at the top of the bridge, whereas Wakefield allowed the air to enter at the front of the bridge at B, facing the fire, and he also made allowance for the admission of air at the side of the furnace to the top of the fire.

PLATE No. VI.—Gilbertson's patent, No. 5,601, 1828.—This arrangement was principally to heat the air supplied to the gases. The air was supplied by hollow plates of iron A, at the furnace sides, and by hollow firebars C C, to the chamber D, and hence by the grated opening at the bridge to the gases.

PLATE No. VII.—Williams's patent, No. 8,118, 1839.—C. Wye Williams may be said to have been the first individual who seriously and scientifically considered the practical combustion of coal without smoke. His book on this subject, even at the present day, may be considered unsurpassed, and those interested in this subject should certainly study it. Williams provided for the admission of air to the gases in "numerous finely divided streams."

The furnace front and perforated baffles, shown in Fig. 7, is the arrangement by which he won the prize of £500 given by the Steam Coal Collieries' Association, Newcastle-on-Tyne, for the prevention of smoke whilst burning Newcastle coal in an ordinary marine boiler.

PLATE No. VIII.—Woodcock's patent, No. 1,762, 1854.—This arrangement provides for the admission of air, heated in passages at each side of the furnace, to the chambers D D of ordinary and hanging bridges, from whence, by perforated plates at the back of these bridges, it is discharged to the gases.

PLATE No. IX.—Clark's patent, No. 1,253, 1861.—Air is admitted at the furnace front by a special arrangement of door, and directed upwards against the air plate B, Fig. 1. It is then drawn forwards by jets of steam to mix with the gases over the fuel. This arrangement, due to the application of steam, is not suitable for general marine purposes, but has proved most effectual in its application to land boilers. One arrangement is shown in Figs. 1 and 2, and another in Fig. 3.

PLATE No. X.—Prideaux's patent, No. 3,898, 1872.—Prideaux's first patent dates 1853. This plan had for its object the automatic reduction of the air supply to the gases as the generation of the gases from fresh fuel decreased. The admission of air was gradually reduced and cut off at a fixed interval after firing, depending upon the firing and the nature of the coal. This arrangement answered very satisfactorily, but fell into disuse, due to constant attention required to keep it in order.

PLATE No. XI.—Fothergill's patent, No. 6,051, 1886.—Fig. 1. The object here is to supply streams of air to the gases at the surface of the fuel in a donkey boiler. Of all boilers the donkey boiler is the biggest transgressor in smoke-producing. A piece of ordinary boiler tube from the shell to the firebox forms a passage for the air carried forward by a jet of steam to the distributing box B, and through perforations to the surface of the fuel. Four or six of these arrangements can be placed round a boiler, and answers satisfactorily.

Fig. 2 is a modification of Fig. 1. Flanged rings A are fitted, having a perforated air plate B, and a deflector E, for deflecting the air to the fire. A steam jet D is used when the coals are exceptionally smoky. Two or three of these are fitted round a boiler, depending upon the diameter of the fire-grate. The writer has fitted them with most complete success.

PLATE XII.—Fothergill's patent, No. 4,937, 1889.—This arrangement was not strictly designed for the prevention of smoke, but to complete the combustion of the gases. The writer in his forced draught experiments found it impossible to get stokers to fire regularly and continuously very short grates. Unless under close supervision they will persist in throwing huge quantities of coal on the fire at one firing, with the disastrous result that large volumes of the hydrocarbon gases are

generated at low temperature and pass away unconsumed. By this arrangement petroleum vaporised, by the waste heat of the funnel gases, is under its own pressure sent into the combustion chamber of a marine boiler at the air distributor D, in conjunction with air supplied under pressure. The vapour is sent into the combustion chamber at a position that can do no harm by intense local heating, and in an opposite direction to that in which the gases leave the fire. As the gases leave the fire and pass the bridge, they are thrown down by the deflector B, and thus brought in intimate contact with the heat of the consumed vapour, and sufficiently heated to take up the necessary oxygen supplied at D, to complete the combustion and prevention of smoke.

The writer regrets that, owing to the depressed times, he had to curtail these experiments.

DISCUSSION.

The PRESIDENT, in calling upon Mr. Mudd to open the discussion, said there was no lack of material, as the writer of the paper had concluded with eight causes for the production of smoke, besides deductions on the opposite side.

Mr. T. MUDD said he thought Mr. Fothergill had given them a very excellent paper. He had drawn together a lot of most useful information on a very important subject. He had given them in a few sheets a summary of all that was known scientifically respecting this very important subject, and he had done more than that, he had given them drawings of a number of patented designs to effect the more complete combustion of fuel, so that at a glance they could see the progress made over a number of years in that direction, and still further he had given them certain tables, so that they might have, as it were, a bird's eye view of the whole question, summarised for them under the heads of "Causes that produced smoke," and deductions as to the steps that were to be taken to prevent it. He thought Mr. Fothergill deserved the hearty thanks of this Institution for the trouble he had taken in giving them that paper. He was quite sure it would be regarded as an important one in the records of this Institution. He had very little indeed to say in the form of criticism. Indeed he had not had time to look the paper over sufficiently to attempt to make any complete criticism of it. He should like to remark on one point, however. Mr. Fothergill's subject was

a sort of double-barrelled one. He called it "The Combustion of Fuel and the Prevention of Smoke." Now, the combustion of fuel—the arrangements made for the complete combustion of fuel—constituted an economic question; the prevention of smoke was mainly a question of the public convenience. He could have wished that Mr. Fothergill had kept these two—both very important questions—more divided. He had, he (Mr. Mudd) thought, rather taken them together, and there were remarks here and there through the paper that seemed to bear out his idea that the two were taken as if they were indissolubly one subject. In the paper (see page 50) they read:—"If the fires are allowed to burn into holes, or the fresh coal supplied be thrown on in an heap, and practically no fires in the corners against the bridge—a very common fault, particularly when using long grates—a very large excess of air flows in from the ash-pit where the grate is bare at the bridge. Under such conditions the air enters the furnace in volume, chills the gases, produces smoke, and reduces the steam." True, it did do that, but the thing was there stated as if it were one effect, and he (Mr. Mudd) wanted to point out that he looked at it from rather a different point of view. He would try to put it this way: if he understood the question rightly, to procure the satisfactory combustion of coal, economically speaking, was a matter that turned mainly on the combustion of the carbonic oxide to carbonic acid. He thought he should be right in saying they could not prevent the production first of carbonic oxide. The question then was—"Shall we let that carbonic oxide slip away up the funnel and so lose the enormous heat-producing power it possesses, or take steps by the introduction of air at a proper place and temperature to ensure its being consumed to carbonic acid?" That was the economic side of the matter, and it was distinct from the smoke question, because carbonic oxide is an invisible gas. Now, in regard to the question of smoke, Mr. Fothergill asked the question on page 44, "What is smoke?" and he rightly answered it. He said it was "unconsumed carbon liberated from the hydrocarbons." He had not followed that up by the statement he should have liked to have seen; that was that smoke, after all, did not involve a very great economic question. Sometimes people seeing a very smoky chimney, said "There goes tons of coal." That was not the case in the sense in which it was meant. A few ounces of carbon would make a very great deal of smoke, and its prevention was really a question of public convenience far more than one of economics. If they took steps, however, to properly introduce air into a furnace so as to complete the combustion of the carbonic oxide, they at the same time almost certainly prevented smoke by burn-

ing the finely divided particles of carbon of which it was composed. Whilst one could not underrate the importance of preventing smoke and so aiding in the public convenience, yet, after all, the production of smoke was not a proof that there was a great waste of fuel going on. The real waste of fuel was invisible.

Mr. J. C. STIRZAKER said he had often observed how little smoke, comparatively speaking, issued from the funnels of fast-running locomotives, especially those upon the main lines. He thought that one reason for this might be the custom, which he understood some railway companies had, of offering premiums to their engine drivers for economy of fuel; and where fuel was economised smoke was kept down. He would recommend that system to factory owners, and suggested that Mr. Fothergill should add it as a sixth deduction to his list. He quite sympathised with Mr. Fothergill's remarks upon the ignorance of factory engineers. The most deplorable fact was they did not know they were ignorant, and so could not be reasoned with or taught. Therefore he thought that if some pecuniary inducement were offered them to economise their fuel, that economy would be effected, and we should see a considerable reduction of smoke in consequence. Referring to the various methods of admitting air to the gases over the fire, he thought that the system of forcing it in by means of a number of small steam jets was perhaps the best. The steam thoroughly distributed the air, and at the same time heated it before it came in contact with the fire or with the furnace plates.

Professor WEIGHTON, M.A., said, to his mind, the subject of the paper was of surpassing importance, not because it had particular reference to such a body as that Institution, but because it had reference to the whole community, and from that point of view he thought the writer of that paper was quite justified in putting the matter as strongly as he had done. He was a little sorry to hear Mr. Mudd put the question as he did, not because Mr. Mudd was not perfectly correct, but because if it went into the public prints, as it might do, it was apt to mislead some in this way, that one might conclude that although there was very black smoke being produced there was no waste of fuel. Now, he thought the whole tenor of Mr. Fothergill's paper, and the whole result of scientific research on the question was, if they had black smoke they had carbonic oxide amongst that smoke, and therefore they had waste. The smoke was visible because of the unconsumed particles of carbon floating about, and although the waste was not inherent in the blackness of smoke, it

was still there in the shape of carbonic oxide gas. Then, again, if they did prevent smoke, he submitted that they also secured economy, not alone and directly through the prevention of the visible smoke, but indirectly through the consuming of the carbonic oxide gas into carbonic acid gas. Mr. Mudd, of course, did not intend to make it appear that the one was inconsistent with the other, but it might mislead outsiders not acquainted with the subject. In regard to the paper, he thought the community was very much indebted, indeed, to any gentleman who brought such a subject forward. He did not know if his hearers felt as he felt personally on this subject, but he thought there was no subject of the present day, excepting perhaps sanitation, which deserved more attention than this question of smoke. If they considered what the cities of this nineteenth century were at the present day, what their atmosphere was, due almost entirely to smoke, and considered what they might be if this smoke was entirely obliterated, surely there was no more important subject that could engage the attention of any body of men. Now, this smoke was admitted on all hands to be a nuisance; but the curious thing was, that whilst admitted to be a nuisance it was also admitted it was not a necessary nuisance, but that it could be prevented. He thought this was generally recognised, and the only part of his friend Mr. Fothergill's paper he should be inclined to question or have otherwise put occurred in the last paragraph, which was rather inconsistent, too, with the whole body of the paper, where he said: "He would venture to suggest to some of the many members of this Institution who are at the head of important engineering works to carry out a few simple experiments, which must necessarily be to their own advantage, and give the public the benefit of their experience." Did not that seem as if they did not know what to do to prevent smoke? whereas Mr. Fothergill had previously told them exactly what to do to prevent smoke. They had got to this stage in the history of this question: that it was perfectly well known how to prevent smoke, and the appliances were ready to hand if they only liked to take hold of them and use them, so that further experiment was only useful for the education of particular individuals, but certainly not for the finding out in ordinary cases of means to prevent smoke. The next point about this nuisance was, that not only was it admitted to be curable, but also that the curing of it would lead to the economising of fuel, and yet it was not adopted. There was no need for him to go into the question of economy, because Mr. Fothergill had pointed out exactly how economy was effected in the prevention of smoke, and it particularly lay in the regulation of the air supply. If sufficient air was admitted and in a

proper way there could be no carbonic oxide passing away and there could be no smoke. The whole question hinged on this air supply. If they could get a sufficient air supply to every furnace they would prevent the production of smoke, provided, of course, they had the supply of fuel as regular at least as the air supply. The next point was clearly brought out in the paper, they could not have a complete, regular, and sufficient air supply unless they had first a complete, regular working stoking arrangement. The principal source of smoke-production (they found it mentioned again and again throughout the paper) was irregularity of firing, leading to holes in the fires, and to great masses of fuel being thrown on at intervals, and these again led to an insufficiency and irregularity of air supply. To secure a continuous supply of fuel over the whole grate, and so to render possible a continuity of air supply, they should have a continuous automatic working furnace which was independent of hand labour. This was the point he wanted to reach, that of the mechanical stoker. Until they adopted some efficient system of mechanical stoking they could not have either the fuel or the air regularly and efficiently supplied. So long as any operation was dependent for its performance upon the human factor it would be fallible and untrustworthy. The more they could remove it from dependence upon mere hand labour the more uniform and trustworthy they made it. Therefore the mechanical stoker seemed to be at least one of the essentials in any real permanent cure for smoke. He did not refer to any particular mechanical stoker, but he knew this, there were a great many working, and working efficiently and satisfactorily. If this was so, that the mechanical stoker properly installed and looked after was a permanent cure for smoke, why was it not adopted and smoke reduced? There were only two reasons: (1) that it did not pay to prevent smoke, or (2) that the virtues of the mechanical stoker, or the means generally of preventing smoke, were not known. One could quite well conceive that the first cost of mechanical arrangements might, in certain cases, be sufficient to prevent the arrangement being adopted, because it would not in those cases pay; but they saw many cases where it did pay, and smoke was to all intents and purposes entirely prevented. Still, there were cases where it would not pay to prevent it, and the only means available then would be to make the consumption of smoke compulsory by Act of Parliament, and to rigidly enforce such Act. On the other hand, a reason for non-adoption might be that the smoke-preventing appliances were not known. If so, then was brought out the usefulness of this paper, which fulfilled a tremendously important function in making such things known.

Mr. TOM WESTGARTH regretted that they had not Mr. Fothergill's opinion on forced draught in relation to the subject of the paper. Judging from what Mr. Stirzaker said, it looked as if forced draught prevented smoke. Mechanical stoking was largely used on shore and found to pay; but had anyone any knowledge of mechanical stoking at sea, for most of those present were interested in marine engines? So far as he knew there was only one generally adopted means of mechanical stoking, and that was an apparatus for working the firebars, which did not deal with putting coal on to the fires. He did not know why such means should not be adopted at sea, and would be glad if anyone would give them information on the subject. Perhaps the most hopeful means of preventing smoke and obtaining economy had been overlooked by Mr. Fothergill, and might have been left out for want of time and space, that was the adoption of gas. He thought there is a great future for the burning of gas for boilers. If they went to the blast furnaces they found boilers heated with gas, and by the use of a simple means for admitting the proper amount of air the combustion of the gas is easily regulated and smoke prevented. He did not see why ordinary boilers should not be fired in that way. Of course, where there were no blast furnaces producers must be put down; but steam could be got by the use of ordinary gas producers quite as cheaply as by the use of coal in the usual way.

Mr. D. B. MORISON said there was a great deal too much smoke came from chimneys, and particularly factory chimneys. This was mainly due, in the first instance, to laziness on the part of the stokers. If intelligent firing was adopted they would at once, even with the present appliances, get rid of at least half the smoke, whilst in land boilers with a good arrangement of mechanical stokers, together with a simple apparatus, such as that proposed by Mr. Fothergill for the admission of air, the smoke nuisance would practically disappear altogether. Mr. Fothergill had done much to show that smoke can be materially lessened by certain simple appliances he had experimented with and brought to a high degree of perfection. These he fully illustrated in his paper, and his proposal to lessen smoke in an ordinary marine donkey boiler was so simple and cheap that it was surprising it had not been more generally adopted. Mr. Fothergill also laid great stress on the admission of air in finely divided jets. He (Mr. Morison) once made an experiment on this point—though, perhaps, of more scientific interest than practical—by putting a number of tubes perforated with small holes above the bridge and connected to

the ash-pit of a forced draught boiler. He found that even with the most careless firing and inferior coal it was possible to almost entirely prevent smoke, except at the first burst when coal was put on. After the apparatus had been in for some days, however, the pipes naturally burnt and were removed. On the whole question his (Mr. Morison's) view was that the prevention of smoke necessitated (1) very careful handstoking, or, better still, stoking by mechanical means, and (2) the proper admission of air by some simple arrangement which was not liable to get out of order.

Mr. G. W. SIVEWRIGHT said he agreed with Mr. Fothergill that to get economy of fuel it was necessary to have careful and regular stoking, as by this means fuel was saved, and they did away with a good deal of the heavy smoke likely to come from furnaces when irregular stoking was carried out. He gathered from the discussion that the only way to get regular stoking was to introduce some system of mechanical stoking. He noticed a short time ago that the boiler of the steamer "Glenariff," of Belfast, was fitted with Hodgkinson's patent mechanical stoker, but he could not say if this arrangement had worked satisfactorily at sea. A little time ago he was through the works of Messrs. Guinness, at Dublin, and in examining the machinery there was struck with the mechanical appliances for lessening manual labour in connection with the firing of the boilers. These works being placed in the middle of a large city it was desirous that little smoke should be made, and on account of the expense only the commonest class of fuel was burnt. The engineer-in-chief, Mr. Samuel Geoghegan, had had a great deal of experience with mechanical stoking, and he (Mr. Sivewright) secured the following particulars from him in connection with the firing and working of the mechanical stokers in use at his works, which he believed would be of interest to the members of the Institution:—Range No. 1: four Lancashire boilers, 7 feet diameter, 28 feet long; furnaces tubes, 2 feet 9 inches diameter, fitted with Bennis's mechanical stoker, sprinkling type; evaporation, about 3,800 lbs. of water per hour per boiler in average work. Fuel used, slack from house coal, making about 11 per cent. of clinker; water evaporated from and at 212 degrees Fah. per lb. of coal, 8·2 lbs. Chimney draught, furnace gases leave 680 to 700 degs. Fah. Range No. 2: three Lancashire boilers, 6 feet 10 inches diameter, 29 feet 7 inches long; furnace tubes, 2 feet 9 inches, fitted with Perrett's water-cased grates made by B. Donkin & Co., London; with forced draught, pressure of air in ash-pits, 1·2 inches of water; evaporation, about 2,700 lbs. of water per hour per

boiler in average work. Fuel used, breeze (gas coke refuse), making about 24 per cent. of clinker; water evaporated from and at 212 degs. Fah., 6·0 lbs. Temperature of gases leaving boilers, 650 degs. Fah. Range No. 3: three Lancashire multitubular boilers, 23 feet long, 7 feet 6 inches diameter; furnace tubes, 3 feet diameter; 332 smoke tubes, 1¾ inches diameter outside, 8 feet 3 inches long. Coking stokers by Cass, of Bolton; strong suction draught by fan between boilers and chimney, which draws air through an air heater heated by products of combustion, thence through the fires and air heater. Water evaporated 8,000 lbs. of water per hour per boiler in average work. Fuel used, slack from house coal, making 11 per cent. of clinkers; water evaporated from and at 212 degs. Fah., 9·0 lbs. Draught at fan, 2·3 inches of water; ditto in smoke box, 1·2 inches; ditto in ashpit, 0·8 inches. Temperature of gases leaving boiler, 650 degs. Fah.; ditto, leaving air heater, 450 degs. Fah.; air delivered to fires, 300 degs. Fah. The above arrangement is not on any special patent.

Mr. W. Kilvington just wanted to say a very few words. He did not like to let the opportunity go past without saying how he appreciated the very valuable and suggestive paper Mr. Fothergill had given them; at the same time he would like to point out that the prevention of smoke was not the very simple thing the writer and Prof. Weighton would have them believe. Prof. Weighton made it very plain sailing until he got on towards the end of his remarks, where he said that the thickness of the fire had to be kept equal, and that the fuel had to be regularly and constantly distributed, but that was a very difficult thing to accomplish. He was not acquainted with the machine that would do it with certainty. He (Mr. Kilvington) had had some experience with mechanical stokers and in letting the air in at different parts of the furnaces; but he often found that, although no smoke was being produced, the coal was not always being burnt economically. It was not, as had been pointed out, the blackness of the smoke that necessarily indicated a bad arrangement of furnace as far as economy was concerned. The great difficulty with mechanical stoking was they had not got a mechanical stoker that would always distribute the fuel in that even and nice way that was necessary to have the smoke prevented. And although they could put the air in in a known quantity, the fuel could not be regulated in the same way, so far as his experience had gone; and therefore, as a manager of works, he thought it was rather hard for the author of the paper to put so much of the responsibility upon them.

Mr. E. HALL-BROWN said he would just like to make the same restriction to Prof. Weighton's remarks that he had made to Mr. Mudd's, inasmuch as he believed that a report of the meeting would appear in the daily press, and it might be that erroneous impressions would be created. One erroneous impression was that if they prevented smoke from the factory boilers, then they would have no smoke in their big cities. That certainly was not the case. The great trouble in cities was not the smoke from the factory boilers, but from domestic hearths. It was of no use putting managers of works and others under restraint while householders were allowed to use the ordinary open coal fire, as they would probably continue to do. The point remained, of course, that black smoke was quite preventible, although, as Mr. Mudd had pointed out, this did not necessarily mean economy. As Mr. Fothergill had said, Welsh coal did not produce the same amount of black smoke that Newcastle coal did, and yet they could burn Welsh coal wastefully, and put two-thirds of it up the funnel, in the shape of carbonic oxide, without betraying its presence as smoke. Prof. Weighton had pointed out that in the long run they must turn to mechanical stoking, and he agreed with him in this. At present, with hand stoking, it was a necessity that a large amount of coal should be put on the fire at once, and necessarily the fire was cooled thereby. In addition, a very large amount of air rushed in during firing, which further cooled the furnace. For a certain period after firing, when the hydrocarbons were being given off, they required a large amount of air above the firebars, afterwards when the hydrocarbons had been driven off they required very little air above the bars. Consequently, an automatic arrangement was required to give the large amount of air after the firing, and to shut it off gradually until a new supply of coal was required. With mechanical stoking the coal could be thinly and uniformly supplied to the fire, and the air supply above and below the bars could be regulated for each quality of coal, and would not vary as long as the quality of coal remained the same, consequently no automatic arrangement would be required. However, until such a mechanical stoker was to be had, and it was proved that it would do the work required of it, he was afraid marine engineers would hang back, and hand stoking would continue. Certainly, marine engineers on this point seemed to be behind the position taken up by their brethren on land. No doubt they had greater difficulties in their way, but he had great hopes that these would be surmounted, and that mechanical stoking would be the stoking of the future, both on sea and land.

Mr. W. G. SPENCE wished to thank Mr. Fothergill for his valuable service in bringing the smoke prevention question again to the front. Unfortunately, this was a subject which had been brought forward intermittently for the last fifty years, in fact ever since Mr. Wye Williams enunciated the principle, which he demonstrated in practice, that smoke could be almost entirely prevented by careful stoking combined with a sufficient and properly distributed air supply. Judging from results, however, they did not seem to get much "forwarder" with it. The problem had been clearly put by Mr. Fothergill in his paper, and he had no wish to criticise anything contained therein, quite the reverse; he thought the principles incontrovertible. Listening to the paper, however, he could not help feeling that, like the bird of old, this smoke question periodically arose from its ashes merely to flap its wings and disappear for another cycle. He was sure that Mr. Fothergill would deserve and receive the thanks of the community if he succeeded in putting salt on its tail and caused this to be positively its last appearance. Smoke from ordinary boilers could undoubtedly be much reduced, he had seen it done frequently, but it required extreme care in stoking, and he did not think they were going to get that care from firemen, and that therefore something radically different was required either in the shape of gas supply or mechanical stoking. In small works probably they seldom would have mechanical stokers, but unless some such device, or special generating furnace was adopted he did not think they would be much farther ahead. As to the question of air supply he had measured that over and over again; it could certainly be too great, but in the majority of cases he had found it too small. The gist of this paper, he thought, was to be found where he understood it often lay in communications of another nature, viz., in the postscript. At the very end was a description of a method of injecting petroleum spray or vapour into the combustion chamber to meet the gases from the furnace. This seemed an original and a good idea, and he hoped Mr. Fothergill would be able to give them some information regarding its working.

Mr. G. H. BAINES said he was not a shipowner, and so could not offer any remarks from that point of view. He was a sort of hybrid between the manager of works who was to be suspended from the gallows and the proprietor of works who must be imprisoned for not consuming his own smoke. However, he must express to Mr. Fothergill and the gentlemen who had followed, his sense of the value of both the paper and the discussion on this subject. He might be allowed to offer one or two remarks

on the non-scientific side of the question. He had lived in a large manufacturing town before he came to reside in that smoky district where a great deal of the smut and smoke, by the way, came with the south wind from Middlesbrough. The manufactures of the town he referred to, Leicester, were largely in the hands of small manufacturers, many with small capital, the manufactures being boots and shoes, hosiery, cigars, elastic web, tapes, and similar articles. They had light machinery with only small boilers, and it would be quite out of the question for these small factories to have mechanical stokers. In 1860, however, the Corporation laid down a very stringent bye-law for the prevention of smoke. They employed one or two police officers who from a high bridge overlooked the town and discovered the offending works, whose proprietors, or stokers, were cautioned and fined on repetition of the offence. Carelessness was the chief cause, but overworking of the boiler was also answerable, yet these small manufacturers could not afford to lay down another boiler to remedy the evil. By and by it came about that with from 150 to 200 tall chimneys there was absolutely no black smoke to be seen in the town. He remembered in his father's factory at that time (1860) there was a device on the furnace door by which, when the furnace had been fired, "baffles" inside the door closed automatically and gradually by a balance arrangement of mercury, and this prevented smoke. He would call attention to the Public Health Act, 1875; as Mr. Fothergill said, if that Act were administered impartially this unnecessary nuisance would be a thing of the past. But then came in the question—at what point shall the Public Health Act interfere with the rights of manufacturers to make smoke? If a Town Council forced men to introduce costly apparatus it might be interfering too much with the manufacture; it was a difficult question at what point the Public Health Act must interfere in certain trades. Something in that way had been done, as he had stated, and more might judiciously be done. He noticed in some of the large new mills recently built in Lancashire that they had introduced the mechanical stoker. In the cotton trade profits were at a minimum; if it paid to provide capital for apparatus for smoke consumption in that trade, surely it would not be much hardship in other trades.

Mr. J. E. STODDART said it had been suggested by some of the speakers that the mechanical stoker would be an improvement for marine purposes, but he did not believe it would give good results, seeing that a vessel at sea is not always upright, and that being so the coal would be fed to one side of the furnace when the vessel listed, and it would be

difficult to keep the firebars well covered when the vessel rolled unless the furnace was made thoroughly accessible, and attention could be given by a fireman in the usual way. Prof. Weighton had said, and he thought it a very proper remark, that little progress had been made with the prevention of smoke, because few people knew what was being done in this matter by inventors. It is well known how much the dwellers in London are troubled with smoke, and it had been stated by the Meteorological Society that nineteen-twentieths of the smoke in a London fog came from the ordinary domestic fireplace. It was therefore a source of satisfaction to know that there was a meeting of experts in London only a few days ago, Sir Edward Reed and the Mayor of Bradford being amongst the number, to witness the testing of an invention for the prevention of smoke which had been introduced by Messrs. Leggott & Marsh, Market Street, Bradford. He understood that the experiments were satisfactory, and the invention was such that it could be applied to all furnaces and fireplaces.

Mr. C. J. Seaman said he was exceedingly nervous and uncomfortable in venturing an opinion not altogether in accordance with Prof. Weighton's. That portion of the Professor's remarks he could not agree with was that which rather "threw cold water" on the last paragraph of the paper. His own feeling was that, although engineers might know pretty well what conditions were required to prevent smoke, owners of boilers did not always know how to secure those conditions in a satisfactory manner under the special circumstances connected with their own boiler arrangements, and he thought some simple experiments as suggested by Mr. Fothergill might be of value in removing some of the black clouds occasionally seen over their chimneys. Mechanical stokers were very good things so far as stoking was concerned, but they often acted as hindrances to the proper supply of air, the majority of those he had seen making it difficult to admit air in the finely divided and distributed streams generally admitted to be the best method. One of the speakers he thought hit the right nail on the head in saying that one of the great difficulties as to the prevention of smoke was that it did not pay when the power required varied considerably. It would be healthy and pleasant to be without smoke, but they all knew that it was not the factories so much as the household grates that were the great sinners in producing the smoke injurious to health. It was well understood how difficult it was to consume smoke in the open hearth, and it was a very amusing and wonderful study to go through the patent records, and see

the arrangements for reducing or preventing smoke in such hearths. He thought they might put it in this way—that forty-nine out of every fifty failed because of some practical difficulty. He remembered in the seventies being interested in the question of heating and ventilating, and finding patent records of an appliance which failed because it was actually impossible to sweep the chimney. It was a splendid idea, had it not been so inconvenient to pull the house down to sweep the chimney. Some of the patents that had been brought forward for the prevention of smoke had failed because some practical difficulty often directly connected with the special boiler or works had been overlooked. People had universally condemned particular plans, because in one or two places for which they were not adapted they did not succeed, whereas they might have been just the very thing under other conditions. He felt the paper was an exceptionally valuable one, and only hoped some method might be found for educating the stokers, so that they might understand the chemistry of the subject and the laws of air currents, and that eventually their labours would be reduced, and the manufacturers' profits increased by a mechanical stoker combined with an arrangement for supplying the requisite quantity of air in the proper manner.

The PRESIDENT said he hoped they would at their next meeting have the pleasure of hearing Mr. H. Fletcher, of Bolton, take part in the adjourned discussion on Mr. Fothergill's paper. Some years ago he commenced to examine the subject of ventilation very carefully, and it was marvellous the results he had obtained. He had taken up this question of the prevention of smoke, and he (the President) was informed that the change he had produced in the Bolton district was astonishing. Mr. Fletcher was chairman of the company for the prevention of smoke, and he thought if they could persuade him to attend their next meeting his remarks would be a valuable addition to the discussion on the paper.

The discussion was adjourned.

ON A SYSTEM OF MECHANICAL AID TO THE INVESTIGATION OF SPEED CURVES.

By J. DENHOLM YOUNG, Wh. Sc.

[Read before the Institution, in West Hartlepool, on Saturday, November 12th, 1892.]

The problems relating to steamship propulsion are of such supreme interest and importance to the engineer and shipbuilder, and in many cases are still so far from accurate solution, that the writer believes that every additional fact and facility may, even if incomplete and fragmentary, be used in the extension of our knowledge and towards the perfecting of our science.

Many theories have been advanced, and methods of calculation advocated concerning the resistance of ships, but upon most of these the great law of "the survival of the fittest," and may we not say, the fittest only, is slowly and surely acting. The theory that seems destined to immortality is due to the inspiration of Sir Isaac Newton, whose mathematical intuitions afforded Rèech the means of enunciating a theorem concerning the similarity of the motions of systems, which the late Dr. Froude re-discovered independently, and applied to the resistances of ships of all forms and proportions, so that viewed from this point of view, what formerly seemed chaos is now reduced to order.

The law referred to may be stated thus: "When the speeds of similar ships are proportional to the square roots of their lengths, then the resistances at these speeds are proportional to the ships' displacements." This is what is now termed Froude's Law, and is strictly intended to apply to wave resistance, but is approximately accurate also when applied to skin resistance.

It follows directly from this law, as is now well known, that with similar models, at corresponding speeds, the effective horse-power is proportional to the $\frac{7}{2}$ power of the length, or the $\frac{7}{6}$ power of the displacements, a result which may be put thus:—

$$H : h :: D^{\frac{7}{6}} : d^{\frac{7}{6}}$$
$$:: L^{\frac{7}{2}} : l^{\frac{7}{2}}$$

where H, D, L refer to the larger model, and h, d, l to the smaller one at corresponding speeds.

From these proportions the effective horse-power of any ship at a given speed may be deduced from that of a similar model at a corresponding speed.

Thus if we have a speed curve of the smaller vessel, and multiply any given speed of the larger one by $\sqrt{\frac{l}{L}}$ we obtain the corresponding speed of the smaller model, and reading off the E.H.P. at this speed multiply it by $\left(\frac{D}{d}\right)^{\frac{7}{6}}$ to obtain the E.H.P. of the larger vessel.

Let us have a ship, for instance, of 400 feet long which we wish to propel at 12 knots. Suppose that we possess the speed curve of a similar ship 100 feet in length. Then the corresponding speed of the smaller vessel will be $12 \times \sqrt{\frac{100}{400}} = 6$ knots. Let the E.H.P. of the smaller model be, say 90, at this speed, then $90 \times \left(\frac{400}{100}\right)^{\frac{7}{6}}$ will give us the E.H.P. of the larger vessel.

The writer has for a considerable time been in search of a handy and rapid method of making the above calculations, and also of a systematic way of recording them when made. In the method which is now to be brought before the members of this Institution, it is only necessary to lay down the original curves to a particular scale on a piece of tracing paper or cloth, and they are ready for application to any size of vessel without reduction or expansion, and generally with only small correction.

In a previous paper recorded in the Transactions the writer described a method of making certain calculations involving the roots and powers of numbers, by means of a logarithmic scale acting after the manner of a slide rule of variable ratios. It is of course unnecessary to explain here that by the use of logarithms, the multiplication of quantities is performed by merely adding their logarithms, while involution and evolution are reduced to the simpler operations of multiplication and division of logarithms. In the common slide rule these logarithms are simply laid down to scale, starting from $\log 1 = 0$.

The diagram for the purpose now before you is based upon these same principles. The logarithms of speeds are laid down on a vertical ordinate on the left, in this case as far as 30 knots. The sloping gradient at the bottom of the diagram is for the purpose of reducing varying displacements or lengths to corresponding speeds, and as corresponding speeds are proportional to the square root of the length or the sixth root of the displacement, the scales are so arranged that if we slide down a certain

value in displacement, $\frac{1}{6}$ of that value is lost in speed, or if length be taken $\frac{1}{2}$ of the value is traversed, whereby we, of course, are dividing by the sixth root of the ratio of the displacements, or the square root of the ratio of the lengths.

Then since by Froude's Law E.H.P. varies at corresponding speeds as the $\frac{7}{6}$ power of the displacement, the scale for reading off horse-power must be set off on horizontal abscissæ in the proportion of 1 to $\frac{6}{7}$ compared with the scale of displacement, or 1 to $\frac{3}{7}$ compared with the scale of length. The scale for length requires evidently to be three times as much extended, or $\frac{1}{3}$ the value, of the scale of displacement, corresponding to the cube root of the same.

Now we take a piece of tracing paper, and rule a base line upon it corresponding to the sloping line in the diagram. Place a mark at the actual displacement of the model whose speed curve is to be recorded, and lay down the curve of E.H.P. This done, we may obtain the E.H.P. of any similar model of different displacement or different length by simply sliding the curve up or down till the original mark reaches the required value of displacement or length. This result is obtained because the tracing is simultaneously moved in a vertical direction to the corresponding speed, and in an horizontal direction to the corresponding horse-power. Thus the one curve of E.H.P. is good for an indefinite number of similar ships within the speeds available. For ordinary purposes, I.H.P. may be put down as being nearly proportional to E.H.P. for similar models at corresponding speeds, an allowance being made for initial friction of engines. A point of some interest may be noted. By always using the same mark on the displacement scale or length scale for the curves of the various models or vessels, we may reduce mechanically and without calculation all types and models to a uniform displacement or to a uniform length, as we desire, thereby having the means of a valuable series of comparisons. Such comparisons were suggested in *Engineering*, July 3rd, 1891, at the very time when the writer was trying to produce a graphic means of performing the operation.

It will be found on reducing vessels to the same length that a correction for length will have to be applied, as skin resistance grows in a less proportion than length.*

It must also be borne in mind that the laws of similarity are intended to apply to the propeller as well as the ship, so that it will be as well to find mechanical means of reducing curves of revolutions to corresponding ones of models differing in size.

* See Froude, Vol. XXIX., *Transactions of the Institution of Naval Architects*, 1888.

If by some magical means we could cause a steamship to grow symmetrically larger, propeller and all, the diameter and pitch of the propeller would preserve the same ratio to the length of the ship, so that if the revolutions remained the same, the speed of the ship would vary directly as her length. But corresponding speeds vary only as the square roots of the lengths, so that to obtain these speeds with similar propellers we must make the revolutions vary *inversely* as the square root of the length.

Suppose, for instance, that we have two vessels, one of 100 feet long and the other 400 feet, then the corresponding speeds are as $\sqrt{100}$ to $\sqrt{400}$, and the corresponding revolutions at these speeds are as $\frac{1}{\sqrt{100}}$ to $\frac{1}{\sqrt{400}}$, or the 400-foot ship will only have half the number of revolutions of the 100-foot vessel. Bearing these facts in mind, the completion of a scale for mechanical reduction to corresponding revolutions is a simple matter. At the bottom of the diagram there is a scale giving speeds corresponding to $\sqrt{\text{length}}$. By drawing "down grade" lines at the same inclination, we at once obtain an inverse scale by their intersection with the lines of speed. Using these points of intersection as abscissa values in the curve of revolutions, numbered for convenience to ten times the scale of speed in knots, it will be seen that in order to have a scope of 300 or 400 revolutions, these scales must overlap each other several times, unless the diagrams were extended to an inconvenient length, when one horizontal inverse scale would serve our purpose.

When comparing the revolutions of different models, it is a more accurate comparison to reduce the vessels to the same length than to the same displacement, since on the same length they have the same corresponding speed. In the diagram, Plate XIII., the curves* of revolutions of the "Edgar" and "Lepanto" are shown, reduced both to uniform displacement and to uniform length, when it will be seen that, owing to the difference in the proportions of the vessels, the revolutions of the "Lepanto" appear to exceed those of the "Edgar," if reduced to the same displacement, more than they actually do. Reducing the vessels to the same length lessens the difference, but still the "Lepanto" has the faster running engines.

At the same time it will be noticed that the excess of indicated horse-power of the "Lepanto" over that of the "Edgar" is increased when the vessels are reduced to the same length instead of to the same displace-

* Taken from *Engineering* for August 24th, 1888, and January 15th, 1892.

ment, which is to be expected, because in the two models of the same length we have one not only of greater beam, but of much greater displacement and fuller coefficient.

An interesting series of curves of I.H.P. has been made, with the permission of Mr. W. H. White, C.B., F.R.S., from his "Notes on recent experience with some of H.M. Ships." These curves are laid down on Plate XV., as reduced to uniform displacement, and on Plate XVI., reduced to uniform length.

With these materials before us the question at once presents itself—With a given type of ship what will be the I.H.P. at a higher speed than has yet been reached? and we may easily slide our curves up to a speed of 30 or 40 knots, but the limits imposed by the weight of machinery must not be left out of sight.

It may be as well at this stage to investigate the effect of the laws of similarity upon our propelling machinery.

The writer referred in a previous paragraph to an imaginary vessel seized with a fit of growing.

At first sight it would strike us that if the ship and propeller increased proportionately, the engines would increase in the same proportion. But this cannot be, for the revolutions diminish while the propeller increases.

Let the mean pressure referred to the low pressure cylinder remain constant, then I.H.P. varies as cubic contents of cylinder × revolutions per minute; but at corresponding speeds I.H.P. varies as displacement $\frac{7}{6}$, and revolutions vary inversely as $\sqrt{\text{length}}$ or displacement $\frac{1}{6}$, so that we have the following result:—

$$\text{Let } C = \text{cylinder capacity.}$$
$$R = \text{revolutions per minute.}$$
$$D = \text{displacement.}$$
$$\text{I.H.P.} \propto C \times R,$$
$$\therefore D^{\frac{7}{6}} \propto C \times R,$$
$$\therefore \frac{D^{\frac{7}{6}}}{R} \propto C,$$
$$\therefore \frac{D^{\frac{7}{6}}}{D^{-\frac{1}{6}}} \propto C,$$
$$\text{or } C \propto D^{\frac{4}{3}}.$$

So that for similar vessels at corresponding speeds the cylinder capacity increases as the $\frac{4}{3}$ power of the displacement. It follows that if the same proportion of stroke to cylinder diameter is maintained,

$$\text{cylinder diameter} \propto L^{\frac{4}{3}}$$

where L is the length of the ship.

This law has an influence upon piston speed, which has had a very practical effect upon our fast liners, although not perhaps hitherto recognised as a logical necessity, at least not formally recognised, for the writer has not met with in other records, the preceding theorem concerning cylinder capacity, nor with any of the theorems that follow.

Let the ratio of stroke to cylinder diameter remain constant, then if

L = length of ship, and since revolutions vary as $\sqrt{\frac{1}{L}}$

$$\therefore \text{ piston speed} \propto L^{\frac{1}{2}} \times \frac{1}{L^{\frac{1}{2}}}$$
$$\propto L^{\frac{1}{2}} \times L^{-\frac{1}{2}}$$
$$\propto \text{stroke} \times (L^{-\frac{1}{2}})^{\frac{2}{3}}$$
$$\propto \text{stroke} \times \text{stroke}^{-\frac{1}{3}}$$
$$\propto \text{stroke}^{\frac{2}{3}}.$$

That is with similar ships having similar propellers and running at corresponding speeds, the piston speed varies as the $\frac{2}{3}$ power of the stroke, so long as the ratio of stroke to cylinder diameter remains constant. This law tends of course to increase the piston speed of fast steamers above a normal value, for as was shown in the paper read by Professor Weighton in 1890, if the strains due to inertia are not to become excessive, piston speeds must vary as the cube root of the stroke. On the other hand, the disadvantage of the excessive cylinder diameter necessary with a short stroke has had its influence in large powers especially, in raising piston speed towards varying as stroke $\frac{2}{3}$.

The effect of these laws of proportion upon the actual dimensions of engines may be best judged by an example. Take for instance the model of the "City of Paris" increased to 700 feet in length.

The speed corresponding to 21·8 knots in a vessel of 560 feet will be 24·37 knots in a ship 700 feet long, and of the same proportions. The diameter of each of the low pressure cylinders will become 148·6 inches in place of 113, thus necessitating the subdivision of the low pressure cylinder into two, each of say 106 inches diameter. The stroke becomes 6 feet 9 inches, and if we take the revolutions of the "City of Paris" as 80, those of the larger vessel would become 70·3, while the piston speed would be increased from 800 feet per minute to nearly 950 feet. Most engineers would, we think, prefer three sets of engines and three screws to a piston speed of about 16 feet per second. The corresponding horse-power would become about 50,470.

On the other hand, take a smaller model, say 140 feet long, propelled as in the larger ship by twin-screws. (The draught is about 6 feet.) Then

on the same proportions the speed becomes 10·9 knots. The low pressure cylinders will be 17·8 inches diameter, and the stroke 9·45 inches. The piston speed is reduced to 252 feet per minute, and the revolutions increased to 160.

With these proportions of engines the I.H.P. will be found to vary as displacement $\frac{7}{8}$, and the cylinder capacity as displacement $\frac{4}{3}$, the mean pressure remaining constant.

Should it be considered necessary in particular cases to adhere to normal piston speed, varying as $\sqrt[3]{\text{stroke}}$, it will be found that mean pressure remaining constant, stroke will have to vary as the $\frac{3}{4}$th power of the length of the ship, and cylinder diameter as the $\frac{13}{8}$th power of the ship's length. These ratios may be combined as follows :—

$$\frac{\text{Stroke}}{\text{diameter}} \propto \frac{L^{\frac{3}{4}}}{L^{\frac{13}{8}}} \propto \frac{1}{L^{\frac{7}{8}}}.$$

It will be more convenient, perhaps, to say that if we are to preserve the above conditions in similar models at corresponding speeds, the ratio of cylinder diameter to stroke will have to be increased in proportion to the $\frac{7}{8}$th power of the length of the ship. (See Appendix for proof of these theorems.)

It is evident that scales of this nature might be laid down at the base of the diagram just in the same manner as I.H.P. But the variations of mean pressure and of stroke ratio are so manifold that such scales would be apt to become misleading. Nor does it require much foresight to see that such a variable ratio of stroke to diameter, as the law of inertia inclines us to, would soon lead us up to excessive enlargement or multiplication of low pressure cylinders, so that we must consent to the necessity of increasing piston speed in the ratio of the $\frac{5}{8}$th power of the stroke, in cases when high speed is the principal feature of the vessel, so long as the present type of engine remains in use.

Leaving the question of revolutions, and referring to the curves on Plate XIII., the relative "indicated thrust" of the two models, "Lepanto" and "Edgar," will be found laid down. It has been taken as near enough the truth that true resistance, for similar models at corresponding speeds, is proportional to indicated thrust. Strictly speaking, the net resistance should have formed the curve, and, as at corresponding speeds, the resistance varies as the displacement for similar models, we may lay down the curve of indicated thrust on the same ordinates as those given for the displacement, dividing the numbers, say by 10, to bring the curve to a convenient size.

Here it will again be noticed that the indicated thrust of the "Edgar"

is considerably less than that of the "Lepanto," even when brought to the same displacement of models.* The wavy character of the thrust curve, resulting from similar features in the curve of I.H.P. in the "Edgar" trials, must attract attention. At corresponding speeds these undulations, probably due to phases in wave resistance, should repeat themselves in similar models if tried, as may be gathered from the paper by Mr. W. H. White, in corresponding depth of water.

Lord Kelvin, in a lecture to the Institution of Mechanical Engineers upon ship waves, has referred to Scott Russell's experiments relating to a "Critical Speed in Vessels," viz., a speed at which the power seems to become disproportionately great to the speed produced. At the extremity of the "Lepanto's" curve, as given in *Engineering*, and transferred to the diagrams, Plates XIII. and XIV., it will be noticed that there is a point in the curve where a tangent to it would become parallel to the gradient at the base of the diagram, then immediately after that the tangent becomes more nearly horizontal than the bottom gradient itself. This point is worth noting, because it is apparent that we could slide the curve up the gradient, *thereby increasing the displacement, still maintaining the same speed, but without increasing the indicated horse-power.*

This point in the speed curve may not be just where the efficiency of the propeller becomes so small as to set a practical limit on the further attainment of speed, although every combination of ship, engines, and propeller must have such a limit. Yet from a commercial point of view, and sometimes in warships from a tactical point of view, this point may justly be called a limiting speed of a very definite character, viz., the speed in any model when we may increase the displacement without increasing the indicated horse-power.

The amount of possible increase of displacement with the I.H.P. that has been attained may be found by drawing a line from the extremity of the curve, parallel to the displacement scale, when the length of the line intercepted by the curve will, when measured from the mark of displacement, give the amount of possible increase in displacement of a similar vessel at the same speed and the same I.H.P.

By calculation we may prove that, taking the "Lepanto's" speed curve as correct, a similar model of at least 17,000 tons displacement may be driven at a speed of 19·1 knots with the same, or less, horse-power, the I.H.P. coming out as 19,500 for 17,000 tons displacement. The speed of 19·1 knots on the larger model corresponds to a lower speed on the smaller one, and at a point *before* the hump occurs.

* The figures for thrust in *Engineering* seem to have an error of one decimal place.

The writer now leaves this subject to the consideration of the members, with the hope that for the fuller elucidation of it, the years to come will give us a better harvest of trial trip data and tank experiments than the past.

APPENDIX.

Proof Regarding Law of Cylinder Diameter and Stroke.

Mean pressure remaining constant, then if piston speed is to vary as $\sqrt[3]{\text{stroke}}$.

$$\text{Let } d = \text{diameter of cylinder,}$$

$$\text{speed of piston} \propto \frac{\text{I.H.P.}}{\text{area of cyl.}}$$

$$\therefore \text{ stroke}^{\frac{1}{3}} \propto \frac{L^{\frac{1}{2}}}{d^2} \text{ at corresponding speeds,}$$

$$\therefore S^{\frac{1}{3}}d^2 \propto L^{\frac{1}{2}},$$

$$\therefore S^{-\frac{1}{3}}(Sd^2) \propto L^{\frac{1}{2}},$$

$$\text{but } Sd^2 \propto D^{\frac{1}{2}} \propto L^{\frac{1}{2}},$$

$$\therefore S^{-\frac{1}{3}}L^{\frac{1}{2}} \propto L^{\frac{1}{2}},$$

$$\therefore S^{-\frac{1}{3}} \propto \frac{L^{\frac{1}{2}}}{L^{\frac{1}{2}}},$$

$$\propto L^{\frac{1}{2}-\frac{1}{2}} =$$

$$\propto L^{-\frac{1}{3}} = L^{-\frac{1}{3}},$$

$$S^{-\frac{1}{3}\times\frac{1}{3}} \propto L^{-\frac{1}{3}\times\frac{1}{3}},$$

$$\therefore \text{ stroke} \propto L^{\frac{1}{9}},$$

if piston speed is to vary as $\sqrt[3]{\text{stroke}}$.

Also

$$\text{since } S^{\frac{1}{3}}d^2 \propto L^{\frac{1}{2}},$$

$$\therefore d^2 \propto \frac{L^{\frac{1}{2}}}{S^{\frac{1}{3}}},$$

$$\propto \frac{L^{\frac{1}{2}}}{(L^{\frac{1}{9}})^{\frac{1}{3}}},$$

$$\propto \frac{L^{\frac{1}{2}}}{L^{\frac{1}{3}}} \propto L^{\frac{1}{6}},$$

$$\text{cylinder diameter} \propto L^{\frac{1}{6}} = L^{\frac{1}{12}}$$

To prove this result—

$$\text{I.H.P.} \propto \text{diameter}^2 \times \text{stroke} \times \text{revolutions},$$

$$\propto L^{\frac{1}{6}} \times L^{\frac{1}{9}} \times L^{-\frac{1}{2}},$$

$$\propto L^{\frac{1}{6}-\frac{1}{2}} = L^{\frac{1}{3}} = D^{\frac{1}{2}} \text{ as before.}$$

DISCUSSION.

Professor WEIGHTON said he did not rise for the purpose of criticising this paper. He thought it would be a very poor compliment to pay the writer of the paper to criticise it in a superficial way, and that was the only way he could at present do it. Such a paper required very deep study. He thought he comprehended the most of it, except that about the end; he did not quite see the drift of it in regard to the possibility of driving a similar ship of a greater displacement at a higher speed with the same power, or at the same speed with less power. He did not quite understand the application to this of the part that dealt with the revolutions of the engines. The rest was quite well understood, viz., given any type of ship, and by type he meant a certain definite ratio between length, breadth, and draught, and a certain coefficient of fineness; and given the result of progressive trials over a wide range of speeds, of any one ship of that type, they could expand or contract that ship to any extent, keeping it to the same type, and so long as they kept the efficiency of the engines and propeller the same they could ascertain the power for any speed within certain limits. The new point in this diagram, as far as he could understand it, besides the investigations which the writer submitted with regard to the machinery revolutions question, consisted in showing this law, usually known as Froude's Law, in a new graphic form. There were other well-known forms; but this one seemed more comprehensive and embraced more than any other he knew, and he thought it redounded a great deal to the writer's credit that he had investigated it in this new way and put it down in this new fashion. A point he would suggest to the writer, in order to make the application of the method clearer, was to append an example.

The discussion was adjourned, and the meeting dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

NINTH SESSION, 1892-93.

PROCEEDINGS.

THIRD GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON WEDNESDAY EVENING, DECEMBER 14TH, 1892.

ROBERT THOMPSON, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting, held in West Hartlepool, on November 12th, which were approved by the members present, and signed by the President.

The ballot for new members having being taken, the President appointed Messrs. Alex. Taylor and J. R. Fothergill to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Atkinson, F. C., Marine Engineer, 123, Croydon Road, Newcastle-on-Tyne.
Gearing, Ernest George, Engineer, 76, Cardigan Road, Headingley, Leeds.
Jeffrey, Philip, Engineering Draughtsman, 98, Park Road, Newcastle-on-Tyne.
Shute, A. E., Marine Engineer, 248, Burley Mount, Leeds.
Surtees, Francis V., Shipbuilder, 5, Westbourne Street, Stockton-on-Tees.

MEMBER (LATE GRADUATE).

Bryson, John Joshua, Engineering Draughtsman, 4, Hartington Street, Barrow-in-Furness.

GRADUATES.

Bentham, Frederick Lister, Engineering Student, 9, Bellegrove Terrace, Newcastle-on-Tyne.
Bryers, Charles, Apprentice Engineer, 10, The Avenue, Sunderland.
Creighton, Alexander, Ship Draughtsman, 31, George's Road, Newcastle-on-Tyne.

Davis, James Albert, Ship Draughtsman, 4, Dickinson Crescent, Gosforth, Newcastle-on-Tyne.

Davison, William H. G., Apprentice Engineer, 49, Sanderson Road, West Jesmond, Newcastle-on-Tyne.

Donovan, John, Apprentice Engineer, 5, Ash Place, Sunderland.

Evers, Ernest Henry, Ship Draughtsman, 7, Bentinck Crescent, Newcastle-on-Tyne.

Hamilton, Robert C., Apprentice Engineer, 2, Dene Crescent, Walker-on-Tyne, R.S.O.

Hardy, Arthur, Apprentice Engineer, 5, Warwick Place, Newcastle-on-Tyne.

Kitchin, Arnold, Apprentice Engineer, 1, York Place, East Hartlepool.

Lishman, John James, Apprentice Engineer, 16, Lovaine Place, North Shields.

Marshall, John Richardson, Apprentice Engineer, 217, Jefferson Street, Newcastle-on-Tyne.

Menzies, Allan R., Ship Draughtsman, 34, Grove Street, Newcastle-on-Tyne.

Morton, John, Apprentice Engineer, 29, Azalea Terrace North, Sunderland.

Murray, George Harper, Ship Draughtsman, c/o Mr. Hill, 126, Church Street, Walker-on-Tyne, R.S.O.

Pettit, Arthur Edward, Engineering Draughtsman, 1, South Crescent, East Hartlepool.

Spencer, Harry John, Apprentice Engineer, 3, Victoria Street, Newcastle-on-Tyne.

Summerson, Benjamin, Engineer, Dene Crescent, Walker-on-Tyne, R.S.O.

Weightman, Thomas, Ship Draughtsman, 179, Portland Road, Newcastle-on-Tyne.

THE GOLD MEDAL AWARDS.

The PRESIDENT announced that the Council had awarded the gold medals for session eight as follows :—

The Engineering Medal to Mr. J. Jennings Campbell for his paper "On Engines for Ships of War."

The Shipbuilding Medal to Mr. M. C. James for his paper "On Tonnage Measurement."

The medals will be presented at the next General Meeting of the Institution.

THE VISIT TO THE ATLAS WORKS, SHEFFIELD.

The PRESIDENT stated that the Council had agreed that the balance of £6 4s., resulting from the visit of the Institution to the Atlas Works, Sheffield, should be contributed to the workmen's sick fund; and the same having being placed in his hands for that purpose, he had forwarded a sum of £10 to Messrs. John Brown & Co., from whom he had received the following letter :—

ATLAS WORKS, SHEFFIELD,
13th December, 1892.

ROBERT THOMPSON, ESQ.,

MY DEAR SIR,—In the absence of my father to-day, I beg to thank you for your letter of yesterday, enclosing the kind contributions of yourself and the North-East Coast Institution of Engineers and Shipbuilders towards our workmen's sick fund. Your kindness in this matter will be much appreciated by all of us.

Believe me, yours faithfully,
CHARLES E. ELLIS.

THE HARTLEPOOL MEETING.

The PRESIDENT took occasion to observe that the last meeting of the Institution at Hartlepool had been a very successful one, the room was full, and the discussion was kept up from beginning to end. The Council were very much pleased with the reception and with the discussion that took place upon the papers then read.

The discussion on Mr. J. R. Fothergill's paper on the "Combustion of Coal and Prevention of Smoke" was resumed.

The discussion on Mr. J. Denholm Young's paper "On a System of Mechanical Aid to the Investigation of Speed Curves" was resumed.

Mr. D. B. Morison read a paper on "Marine Boiler Furnaces."

ADJOURNED DISCUSSION ON MR. J. R. FOTHERGILL'S PAPER ON THE "COMBUSTION OF COAL AND PREVENTION OF SMOKE."

Mr. J. R. Fothergill's paper on the "Combustion of Coal and Prevention of Smoke" was again submitted for discussion.

The SECRETARY read the following:—

COMMUNICATION FROM MR. JOHN F. WALLIKER.

DEAR MR. DUCKITT,

I am sorry that a previous engagement of old standing prevents my being present at the meeting on Wednesday, at the same time I should like to be permitted to make a few remarks on the subject of Mr. Fothergill's paper, "Combustion of Coal and Prevention of Smoke."

The subject-matter appears to me to point principally in the direction of smoke prevention and consequent coal economy on land, but the vital importance of it to this coal-producing district in the North of England for marine purposes should, in my opinion, not be overlooked when discussing the question. It is, of course, well known that our fuel is practically debarred from use in the Navy from the great smoke drawback, and any suggestion for the adoption of means to obviate this should have the immediate consideration of all interested. Professor Weighton stated, in his remarks, "that we have got to this stage in the history of the question that we knew exactly what to do to prevent smoke," and it would then appear that we have to apply it on board ship in order to get the best value out of our coal. From reasons well known to all, mechanical stokers are inadmissible at sea, they have been tried often and found wanting, especially in heavy weather, but the adoption of shorter bars, large furnaces, and trained stokers would do much towards reaching the goal. The Navy, if any one, should be able to take up this question and work it to a definite issue, they have every opportunity of trying the various systems, and a body of stokers unsurpassed at their work. Until we have better supervision over our stokers in the mercantile marine there will ever be the same complaint of gear breaking down or being too complicated for everyday use. Anyone is supposed to be able to fire a boiler with bars 5 to 6 feet long, whereas, as is well known, it requires both judgment and skill to do this efficiently. I can quite endorse Mr. Fothergill's remarks with regard to Prideaux's patent doors.

I have had some experience with them, and made some experiments with them, and the result was that they efficiently prevented smoke, but added little to the economy. Unfortunately, their rather delicate anatomy also exposes them to the charge of being easily put out of order. Some very interesting experiments were carried out on the Tyne two or three years ago with a zig-zag bridge in the combustion chamber, composed of fire-brick, and which was extra-heated by forced draught and the smoke led through this before passing into the tubes. The adoption of this had many drawbacks in marine boilers, the principal one being the inaccessibility of the back ends from the brick erection, but its success as a smoke preventer was undoubted.

Yours faithfully,

JOHN F. WALLIKER.

There being no further remarks offered, Mr. Fothergill was called upon to reply.

MR. FOTHERGILL'S REPLY.

Mr. J. R. FOTHERGILL, in reply to the criticism on his paper, said he thought Mr. Mudd was misled by the wording of the title in his assumption that it would have been better to have divided the paper under two heads. First :—The combustion of fuel. Secondly :—The prevention of smoke. Had the title been worded "The combustion of coal *to the* prevention of smoke," instead of "The combustion of coal *and* prevention of smoke," he thought it would have prevented the error into which Mr. Mudd had fallen. It was not his intention to consider the combustion of coal to evaporative efficiency—steaming, but to treat the subject entirely as a question of consuming coal without smoke. Undoubtedly the two questions were dependent one on the other, and therefore it was practically impossible to fully consider one without some reference to the other. Mr. Westgarth alluded to the advantage of gas producers. He (Mr. Fothergill) was of opinion the gas producer had many advantages. In fact some years ago he was so impressed with its advantages that he went seriously into the question of applying the producer to marine boilers, but so many practical difficulties interposed, such as room required, weight and character of material of the structure, that he gave it up. He thought for land purposes the gas producer was most valuable, and if more thoroughly understood would have a large application. He had to thank Mr. Sivewright for the very interesting particulars he had

given relative to mechanical stokers. He hoped to have been able to put before the meeting a communication from Mr. Herbert Fletcher who was perhaps more thoroughly acquainted with this question than most people, as his experience as honorary secretary of the National Smoke Abatement Institution for Testing Smoke-preventing Appliances enabled him to speak with great authority. He felt sure the Institution would heartily appreciate any communication Mr Fletcher should send. There was one feature of the discussion which undoubtedly bore strongly on the question of smoke prevention from a manufacturer's point of view and that was the question of economy. Was there economy in the prevention of smoke? He noticed that at least three of the speakers in particular had spoken pertinently to this point, and in doing so had expressed the opinion that so far as the smoke, viz., the carbon liberated from the hydrocarbon gases which discoloured the escaping gases was concerned, the loss was comparatively small, but that the liberation of this carbon was synonymous with the production of carbonic oxide, which oxide, not being consumed to carbonic acid, represented considerable loss. Now, what he thought desirable to point out was this:—The production of smoke does not, by any means, imply the production of carbonic oxide. Carbonic oxide is much more difficult to produce than carbonic acid, and it was only formed under exceptional conditions coupled with great deficiency in air supply. It was exceptional to find carbonic oxide in any material quantity as one of the products of combustion, and thus it would appear that the actual loss was little more than the value of the escaping carbon. That was an important point, and, judging from the discussion, not fully understood. It was a mistake to imagine that in the combustion of carbon, carbonic oxide was first formed and then consumed to carbonic acid. In confirmation of this he had tabulated the analysis of the funnel gases taken from various steamers during the marine engine trials made by the Institution of Mechanical Engineers. These results were most interesting. (See next page.)

The table showed the pounds of air supplied per pound of coal varied 100 per cent., and they further noted the pounds of coal burnt per square foot of grate had even a greater variation. The coals in each case were different, and the conditions of air supply were different. The first four boats were under natural draught conditions and the last two under forced draught, and in one case Henderson's firebars were fitted. Yet there were only two examples of carbonic oxide being formed. Out of the twenty samples taken in the case of the "Colchester" they found only ·23 per cent. of carbonic oxide, representing a loss of 1·3 per cent. of

the calorific value of the fuel. In the case of the "Meteor," although several samples were taken, yet, unfortunately, they were all spoiled except one. It was more than probable the mean of a number of samples would have shown a material less percentage than that in the analysis given, yet the ·8 per cent. of carbonic oxide found only represented a loss of 3·6 per cent. of the calorific value of the fuel. The committee reported in the case of the "Meteor":—"Very much smoke was always emitted after stoking, but while no stoking was actually going on there was not much smoke. Stoking occurred about every 24 minutes." In the case of the other steamers, with the exception of the "Iona," the smoke was of the usual quantity in accordance with the coal burnt.

Steamers.	Number of Samples.	Per Cent. by Volume.				Lbs. of Air per Lb. of Coal.	Coals burnt per Sq. Ft. of Grate per Hour.	Coals.	Remarks.
		Carbonic Acid.	Carbonic Oxide.	Oxygen.	Nitrogen.				
Meteor ...	1	12·50	0·80	5·40	81·20	15·5	19·25	Scotch ...	N.D.
Fusi Yama	2	7·53	0·00	11·57	80·90	22·8	18·98	Tyne ...	N.D.
Colchester	*20	9·25	0·23	10·04	80·48	18·5	26·10	Yorkshire .. / Nottinghamshire ..	N.D.†
Tartar ...	21	6·72	0·00	13·12	80·16	31·6	11·93	Welsh ...	N.D.
Iona ...	13	8·20	0·00	11·17	80·63	24·5	22·40	Tyne ...	F.D.‡
Ville de Douvres...	*18	11·55	0·00	7·95	80·50	17·9	31·30	Belgian ...	F.D.§

N.D. Natural draught. F.D. Forced draught.
* Mean—two funnels. † Henderson's firebars. ‡ Closed ash-pits. § Closed stokehold.

The economy gained by the application of the mechanical stoker was principally due to the fact they were able to consume to efficiency and without smoke a cheap inferior coal. This was due to the mechanical, regular, steady feeding of the coal to the furnace which got rid of the greatest difficulty, viz., manual stoking.

He thought he had in the discussion a very good apology, if such was needed, for being emphatic in his opinion that owners and managers should be made responsible for the production of smoke. He found, with scarcely an exception, all the speakers (and they were principally engineers and managers of works) fully agreed there was no exceptional difficulty in preventing smoke, that being so, was he not justified in asking why should a public nuisance and annoyance be tolerated for the sake of individual advantage or gain?

He felt the greatest satisfaction for the manner in which his paper had been received, and begged to tender his most hearty thanks to the members for their liberal and impartial discussion.

On the motion of the PRESIDENT, a vote of thanks to Mr. J. R. Fothergill for his interesting paper was carried by acclamation.

The following communications were subsequently received on the subject:—

COMMUNICATION FROM MR. HERBERT FLETCHER.

DEAR MR. DUCKITT,

The legal difficulty in the way of clearing our skies is greater than the mechanical.

Reformers will find it harder, under our present local government arrangements, to persuade owners of works to use the proper means for preventing the common, though illegal, issue of smoke from their chimneys, than either to discover or to apply those means.

The remark at the conclusion of Mr. Fothergill's paper, that "probably some form of mechanical stoker will in time prove the solution of the present stoking difficulty," suggests to me to draw the attention of the Institution to the work of the National Committee for Testing Smoke-preventing Appliances, inaugurated two years ago, the address of whose secretary (Mr. Fred. Scott) is 44, John Dalton Street, Manchester. The details of this work belong to the subscribers, but I may say that they already, though incomplete, confirm Mr. Fothergill's supposition, and this, moreover, without involving a sacrifice of either power or economy, as I will relate further on. Mr. Fothergill's history of the mechanical means may be accompanied by a history of recent efforts to put the law in force, or of the crusade which is now being waged in Lancashire with every prospect of replacing in four or five years the week-day atmosphere by that of a Sunday. Twenty-four years ago, in 1868, the Local Government Board held a public enquiry in Bolton at the instance of fifty memorialists, who complained to it of the neglect by the corporation of the smoke provisions of section 91 of the Public Health Act. The commissioner, Mr. Arnold Taylor, was informed by the borough inspector, that of the seventy principal firms all were doing something, that two satisfactory methods for preventing factory boiler smoke were in use, and that the nuisance, if given breathing time, would reform itself. Upon the strength of this information Mr. Arnold Taylor recommended that legal proceedings to enforce the Public Health

Act should not be resorted to. The post of smoke inspector to the borough was thereupon abolished. The nuisance grew unchecked, till the writer entered the council six years ago for the express purpose of bringing the subject forward. I had at that time been using the Cass coking stoker on six colliery boilers for ten years, and was able to show the sanitary committee a smokeless chimney serving three 7 feet 6 inch Galloway boilers, each burning 7 cwt. of fine slack per hour, with an indifferent draught given by a chimney 25 yards high and 3 feet square inside at the top. I could also take them to a good example of the Vicars, and of the Sinclair or Bell-Sinclair, and of the old Juckes system, all of these costing between £75 and £100 a boiler, and producing smokeless chimneys, but it was the application of Roscoe's split bridge, in principle as old almost as steam boilers themselves, and costing only £8 a boiler, that probably influenced the Sanitary Commission more than the better systems, and induced them to recommence the prosecutions, which had been discontinued for eighteen years on the recommendation of the Local Government Board Commission. The committee were convinced of the practicability of making steam without smoke, and fixed 2½ minutes of dense, or 10 minutes of medium, black smoke as a temporary standard for the three nuisance-inspectors, who thereupon began again to fill up in their reports the vacant spaces devoted to smoking chimneys, and some thirty orders-to-abate have since been obtained from the borough bench.

Deputations from the corporations of Rochdale, Blackburn, Bury, Oldham, Middleton, and many local boards followed the Bolton Corporation in the round of visits to smokeless works, and the corporation of Rochdale passed a resolution that there was to be found in the market apparatus by which coal could be burnt for trade purposes economically and smokelessly. The larger boroughs named are now all prosecuting.

There were eighteen prosecutions in Bolton last year; eight of these were dismissed on technical grounds, but the corporation were encouraged by the increasing applications of successful appliances, and by obtaining an order-to-abate against a large firm outside the borough under an unused section, No. 108, which gives power to either urban or rural sufferers from a nuisance to proceed against the causers thereof though they may be beyond the boundary of the district affected. They were also incited by the facilities obtained by Oldham, and have lately applied for increased powers by provisional order, the public enquiry on which was held during November last, and elicited no opposition.

A magistrate, who had been prosecuted, came forward, contrary to

expectation, and told the commissioner of the success of the apparatus, he had since applied, burning 20 tons a week of 60 hours in each of two 7 feet Lancashire boilers and saving on each £1 a week in the price of cheaper fuel. There were also letters from two of the largest firms in the town giving similar encouragement, and the commissioner was informed that the town could now show 21 chimneys, out of some 200, that did not exceed the corporation's standard of 2½ minutes' dense, or 10 minutes' medium, black smoke in the half-hour, of which chimneys 14 were practically smokeless, though serving 33 boilers, all heavily fired—that is, burning at least 20 tons in 60 hours.

The main features of these increased powers are the dispensing with the order-to-abate of the local bench, as has been done in Oldham, substituting for it that of the corporation, and the doubling penalties of the metropolis; the penalty for the second offence being fixed at £10, the first being anything under £5.

During the summer the Bolton Corporation passed a resolution requesting the co-operation of the Lancashire County Council in suppressing the smoke nuisance, and on the 3rd November the County Council passed the resolution "That the time had arrived when the County Councils of the country should be empowered to administer the Public Health Act concurrently with the local authorities at present charged with that duty." The medical officer of the County Council had paved the way for this resolution by drawing attention to certain gross cases of neglect by local authorities in cases of nuisance, and answers to special questions asked by him of the local authorities in the administrative county, showed that the smoke provisions were a dead letter. If other authorities will take action, as Bolton has done, and will seek similar powers, or if the County Council should obtain only the present powers of the Public Health Act, to say nothing of these new Bolton ones, and will use them, they can with the evidence now at their service obtain convictions, and make obedience to the law a matter of business, that is, one worth the attention of men of business, which at present it scarcely is. Dr. Patterson, of Oldham, is prosecuting as a private person "aggrieved," and has obtained 200 convictions. His pamphlet, published by the *Oldham Chronicle*, is now the best guide to both prosecuted and prosecutor, and it is due to his energy that Oldham now rivals Bolton in the number of her smokeless factories.

The National Committee, above alluded to, have come forward as the friend of the prosecuted, no less than of the public, to do for the steam-users of the country what no one of them could do for himself.

The main object of the committee is not to classify second-rate systems, as for distribution of prizes, but to discover the best system, and its second is to ascertain what, if any, burthen is imposed on the steam-user by the requirements of the Public Health Act. The score of careful tests, that have been made by the engineers of the committee, and by Professor Kennedy in London for the committee, have gone far to realise these two objects. A difference of 50 per cent. in power (or that between 510 and 751 gallons per hour per 7 feet boiler) and 33 per cent. in economy (or that between 6·58 and 8·80 lbs. of water per lb. of small coal), the coal making respectively 12 and 17 per cent. of ash and clinker, with similar temperatures of feed-water and of steam, and similar power of draught, make great accuracy in these tests unnecessary. Between the best examples of boiler-firing, that could be found in Blackburn, Bolton, and Widnes, the differences, named above, were found to exist, and they showed to the credit of the smokeless practice.

The mechanical stokers act on one or other of two principles, "sprinkling" or "coking." In the sprinklers a shovel, actuated usually by springs, or a revolving drum or disc, receives the coal in small quantities from the hopper above and flips or sprinkles it over the surface of the fire. Moving bars usually accompany these, but are not indispensable, as they are with the cokers.

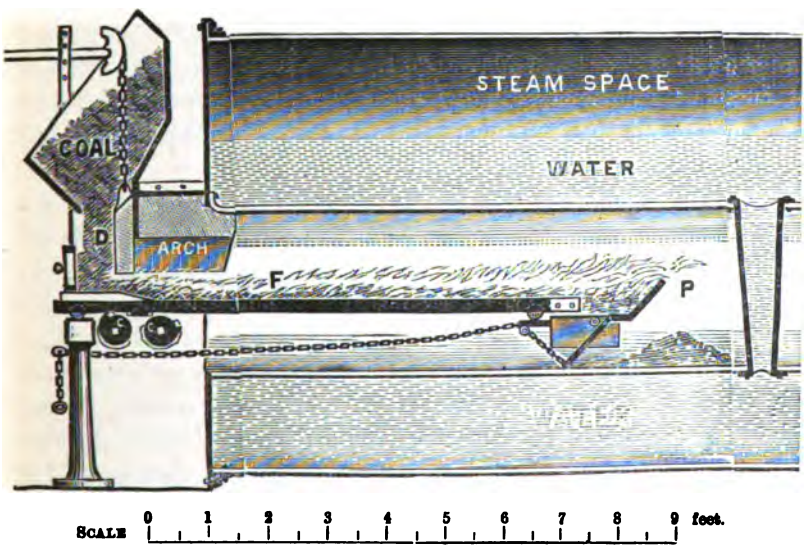
They do not approach the cokers in smokelessness, substituting, as they usually do, continuous black smoke of medium density for the intermittent but denser emissions of hand-firing. The sprinkler makers are Proctor, Bennis, Hodgkinson, Whittaker, and Dilwyn-Smith.

Of the coking stokers, the Cass machine (see sketch opposite) may be said to move the fuel as did the old Juckes furnace, which, however, is not economical, and not applicable successfully to internally-fired boilers. In the Cass stoker the moving bars take the stream of fuel beneath a brick arch at white heat, which ignites the fuel on the surface. By the time the coal has reached the far end of the furnace complete combustion has occurred, the ashes are dropped over the bar ends on to the bottom of the flue, and neither is rake or poker required, nor is any opening of the fire-door necessary from the starting to the stopping of the engines.

The makers of the cokers are Messrs. Cass, Vicars, Sinclair, and Hodgkinson. The Helix and Henderson's may be regarded as amphibious machines, half-way between plain hand-firing and the cokers. All of them can be urged by the rake or poker, but they make smoke, though not all to the same degree, when so disturbed.

All other systems than the mechanical ones of coker and of sprinkler

consist of ordinary hand-firing with the admission of air at the front or back of the fire, or at both. Their success is often considerable in the hands of a careful attendant, having not more to deal with than 24 tons per week (half the usual rate), and that should be of a good quality of lumpy coal or large slack. While the best of the cokers deals with and makes the most of the worst and cheapest slack, and can burn this at the maximum rate of 25 lbs. per foot of fire-grate surface per hour—rendering it possible for one man to attend to three boilers burning each 28 tons per week—all the air-admitting systems require an amount of attention from the fireman in side-firing and distribution of fuel, which has not been yet found consistent with the usual work expected from him of nearly 50 tons per week! This difference involves 6d. per ton in wages, or £30 a year, on a very usual consumption of 1,200 tons per boiler. I have not heard of machine-firing at sea, where it should be especially useful, except with Henderson and also Hodgkinson. The latter in the ill-fated "City of Chicago."



PLAN OF BOILER FURNACE BY MR. THOMAS CASS, OF PALMERSTON STREET, BOLTON.

D. Furnace door, regulating thickness of fuel on bars—lined with bricks.

C. Cams revolving in opposite directions, imparting simultaneous forward and consecutive backward motion to bars, driven by worm and spur wheels, by strap from overhead pulley; the points of contact are provided with removable pieces of hardened steel.

P. The back plate for holding ashes to stop the passage of air between the bar ends.

A. An arch of firebrick for retaining the heat to ignite the surface of the fuel.

F. Fuel on bars—3 inches thick at door—¼ inch thick as clinker, where it drops off the bar end.

I would suggest that the Institution should ascertain the truth of these statements, and then memorialise the Town Councils to put the present law in force, and along with the County Councils endeavour to obtain the powers sought by Bolton and by the Lancashire County Council.

Without communicating figures, which belong to the National Committee, and which can be obtained by subscribers, I may say of the tests referred to, that the best examples of the boilers of the smokeless chimneys beat those of the most smoky ones by more than $\frac{1}{3}$rd in both power and economy, and that they beat those of the medium smoky ones, which include the sprinkling stokers, by $\frac{1}{14}$th in power and by $\frac{1}{7}$th in economy.

Yours faithfully,

HERBERT FLETCHER.

COMMUNICATION FROM MR. OSWALD WHEELER.

December 12*th*, 1892.

DEAR MR. DUCKITT,

I feel that I must first add a share of praise to Mr. Fothergill's paper before making any remarks on it. I think that it will more than sustain the reputation of the Institution, and that both paper and discussion will be of great use to us all.

Mr. Fothergill states that the "pea-soup" fogs of large towns are caused more by the smoke from dwellings than from factories. As the open fire-grate is more remarkable for its inefficiency in warming a room than for anything else, one marvels at its remaining so long without a competitor. There are now, however, other grates to be had which, in addition to burning much less fuel, warm the room much more uniformly and thoroughly. These all work on the principle of warming the air needed by the fire before admitting it into the room. Thus the cold draughts from doors and windows are avoided, and as warm air only is admitted the room has an almost equal temperature. I think that Mr. Fothergill and those of his friends who object to coal-smoke in towns should use this kind of fire-grate. Their houses will be warmer, and they will burn less coal, and as they burn less coal there will be less smoke, so that their personal comfort and interest and the public health will all go hand-in-hand.

I heartily support Mr. Fothergill's suggestion that some more experiments be made and placed on record, and beg to recommend that they take the direction of showing the effect on the consumption per square

foot of grate of different proportions of air-space to solid bar, and also of the effect on the gases of different air admissions over the bars immediately after firing and when the coal has become coked. This latter would enable us to tell whether any variation of air supply was necessary. In the discussion on the paper on "Forced Draught," read to this Institution by Messrs. Patterson and Sandison, two speakers gave instances of the general good effect of supplying plenty of air at the firebars; and Mr. Spence in his paper on "The Combustion of Coal and some Experiments on Natural and Forced Draught" related how, with natural draught, he obtained better results by taking out some firebars. This supply at the bars sets up, to use Mr. Fothergill's happy phrase, an "air-poker" action among the coals. To my best information Mr. Spence was the first to tabulate the proportion of bars to spaces. In all other evaporative tests this important detail is never mentioned: not, I think, because the experimenters wished to keep this tit-bit of information to themselves, but because they never realised its importance. The heat in the furnace is due to the chemical combination of the oxygen of the air with the carbon and hydrogen in the coal; and the firebars and furnace fronts are obstacles to this combination. Therefore I urge that these experiments be made. They will be of great use to the members, especially to the Associate Members, and will do much to increase the fame of this Institution.

Yours faithfully,

OSWALD WHEELER.

MR. J. R. FOTHERGILL'S REPLY TO THE ABOVE COMMUNICATIONS.

DEAR MR. DUCKITT,

I have to thank Mr. Fletcher and Mr. Wheeler for their communications. Mr. Wheeler, I think, has not observed the statement I made in the paper that I did not intend to refer to the domestic grate. The domestic grate is unquestionably a great sinner in smoke producing, and has much to answer for; but I am under the impression it is better to try and stop the smoky factory chimney first, in which we could look for public sympathy, as that is a most powerful lever if properly applied.

Mr. Fletcher has certainly given us, as I anticipated, most valuable information of what has actually been done, and what could undoubtedly

be done if the proper authorities would only throw aside their unaccountable apathy and take up the question as one necessary to the health of the public. Mr. Fletcher clearly and distinctly shows that in Bolton and other large manufacturing districts *coals are consumed without smoke with greater economy;* and that being so, I again ask why is the law not put in force against the smoke producer?

Yours faithfully,

J. R. FOTHERGILL.

ADJOURNED DISCUSSION ON MR. J. DENHOLM YOUNG'S PAPER "ON A SYSTEM OF MECHANICAL AID TO THE INVESTIGATION OF SPEED CURVES."

Mr. J. Denholm Young's paper "On a System of Mechanical Aid to the Investigation of Speed Curves" was resumed for discussion.

The SECRETARY read the following:—

COMMUNICATION FROM MR. W. HÖK.

December 13*th*, 1892.

DEAR MR. DUCKITT,

I had promised Mr. Young to speak on his paper, but finding, however, that I shall be detained on business to-morrow night, I am unable to be present at the meeting. I have therefore put my views hurriedly on paper, which kindly read to-morrow night.

First, with regard to the law of comparison. This law has within recent years so come into prominence that it is as well to make an attempt to trace the divers steps in its evolution. The first step was taken by Newton. He proved the conditions for similarity of motions in celestial mechanics, which conditions he required to know in order to prove the stability of the solar system. The next step was taken by Reech something like 150 years after Newton, and a very important step it was too. It must first be mentioned that in celestial mechanics the law of similarity of motions holds good without any connection between speed and size as is so essential in terrestrial mechanics. M. Reech first modernized what had previously been done by Newton, and then further advanced and completed the general theory of similarity of motions by announcing and proving this important fact, that if it is the question of terrestrial mechanics, such as motions of bodies on which the forces of gravity predominate, the forces acting on the systems fulfil the conditions of similarity only when the velocities of the systems are to one another as the square root of their linear dimensions, which is indeed the law that is

now known under the name of the law of corresponding speeds. As a matter of interest it may also be mentioned that Reech discussed in all its phases the applicability of this law to determine ships' resistances by means of model experiments. The next and final step as regards the application of this theory to ships, was taken by Mr. Froude about forty years after Reech. As is well known Mr. Froude rediscovered this law in the special case of bodies moving on the surface of water through studying Rankine's paper on stream lines, but apart from this, to him, and also I think to Sir Edward Reed, is credit due for having persuaded the Admiralty of testing this law practically, thereby setting at rest the minds of those who at that time were dead against model experiments.

Then with regard to Mr. Young's method of plotting and investigating trial data of steam ships. In many respects, I think, Mr. Young should be congratulated on his method. There is little doubt about this, that for rapidity of estimating powers and speeds of ships his method is without a rival, so where there is a question of merely using the trial data for purposes of estimating, his method must be highly recommended. Besides, it is highly ingenious, and as such must be universally admired. Yet it is not a perfect method. Apart from minor practical difficulties, such as contraction of paper and the extreme smallness of the scale at higher powers and speeds, it has the same fault as almost every known method for recording powers and speeds of ships; and as I think this point most important, I shall try to make myself clear. The fault that I want very particularly to emphasize, not only in Mr. Young's case, is that what you get from your trial data by plotting them in an unnatural fashion is a *distorted* speed curve, a curve that will tell you very little indeed of the true nature of your ship's resistance. What I mean is this, that you efface every possible characteristic of the ordinary and familiar speed curve as first drawn by Mr. Denny by plotting your data in the way proposed. The only thing you can do with a speed curve without robbing it of its inherent characteristics is to multiply the speeds by a *constant* or the powers by a *constant*, or both speeds and powers by *constants*. But if you begin to multiply or divide by *variables* you distort your curve and rob it of all its natural characteristics. And it is my firm belief that by so doing you retard this knowledge of a true understanding of the phenomena of propulsion which we are all so anxious to possess. Mr. Mansel distorts it by using the speeds and the logarithms of the powers; Mr. R. E. Froude, in 1888, by dividing the powers by the cubes of the speeds; and, finally, the Admiralty co-officients, although hard to recognise, what else are they but distorted speed curves inverted?

Now it so happens that there is no need whatever for any expedients of this kind, as ships can be compared without them. It is with this knowledge that I have emphasized the point.

Mr. Young neglects to correct for skin-friction not varying according to the conditions for similarity. Most people do so. However, Mr. R. E. Froude gave us in 1888 the means of effecting this correction, so there is no excuse for not doing it now. This correction is in many cases no unnecessary refinement, the difference in power with and without skin correction being often considerable, as the following example shows:—

Model ship is 100 feet long.

Power to drive modern Atlantic liner 20 knots,

not corrected for friction	22,000,
but corrected for friction	20,000.

Difference, 10 per cent.

I do not know if I can agree with Mr. Young that increase of piston speed in large ships is due to occult influences of the law of comparison. I think it is rather due to its tendency of lightening the engines. I pointed out, now some years ago, in a letter to *The Engineer*, the influence on the size of ship of the weight of machinery varying practically as the 3·5th power of the dimension when the displacement varied only as the cube of the dimension. The influence is so considerable that one has to exercise the utmost care in using this law, which can best be understood by an example. If you quadruple the length of a ship, the displacement of a similar ship will be 64 times the original displacement, and on the assumption that the weight of machinery bears the same ratio to the horse-power in both cases, her machinery is 128 times the weight of the original machinery, it being therefore quite possible that the new ship cannot carry this additional weight without being further enlarged. No doubt the relative weight of the machinery would be somewhat less, due to the higher piston speed that would be adopted. It would, however, not amount to much on account of the relative weight of the boilers remaining unchanged. In connection with this it would be extremely useful to know the variation of weight per I.H.P. of machinery in similar ships; and this Institution would, I am sure, be much obliged to Mr. Young if he could see his way to investigate the matter and add it to his paper.

Only another point and I have finished. On page 78 of his paper, Mr. Young has astonished a great many by the statement in italics that you can at a given speed drive a larger ship with smaller power than a small one. To many it will seem incredulous, but it is nevertheless

a fact. While busy with an investigation in speed matters some five years ago I noticed the same thing. As Mr. Young in his paper has merely stated the case in a very brief manner, I beg to give some additional information on this point, hoping that the very curious results I have arrived at will prove interesting. I have appended a theoretical proof (see page 101), and will here give only the results of my investigation, which can be briefly stated thus:—If over any part of a speed curve, the horse-power varies as the 7th power of the speed, one can, at any fixed speed over this range, drive a larger ship with the *same* power as a smaller ship, the variation of size depending on the range over which the I.H.P. varies as the 7th power of the speed. If the I.H.P. varies at a smaller rate than the 7th power of the speed, the larger ship requires greater power than the smaller at this speed; but, on the other hand, if the I.H.P. varies at a greater rate than the 7th power of the speed it will take *less* power to drive a *larger* ship than a *smaller*. To generalize, if one could imagine a body encountering such a resistance that the power to propel this body varied as the 7th power of the speed over the whole range of speeds, it would be immaterial of what size the body was, as the power at any given speed would be the same whether the body was large or small; and if the power required to propel the body exceeded the 7th power of the speed over the whole range of speeds, the larger the body was the smaller would be the power to drive it, and so on. And the rates at which the horse-power increases with varying displacement and constant speed for the various rates at which the powers increase with speed for constant displacement are given in the proof. Suffice to say here that the easier a body is to propel through a given fluid, that is to say the smaller the rate of resistance is offered by the fluid for varying speed, the higher is the rate of increase of power for varying displacement at constant speed and *vice versa*. That the 7th power of the speed is the limiting rate above which a ship should not be driven agrees with Mr. Young's diagram. If a straight line is drawn parallel to the gradient, this line represents a power curve varying as the 7th power of the speed; and if it is more horizontal than the gradient it varies at a higher rate than the 7th power of the speed.

Although I cannot hope to have made myself understood now, I believe that the facts I have furnished will ultimately prove of interest to the members of this Institution.

Yours faithfully,

W. Hök.

Proof of the proposition that it is possible, under certain conditions, to drive a small and a large ship of similar forms at the same speed with equal powers.

Theorem.—If the horse-power required to drive a ship varies as the 7th power of the speed, the horse-power at any given speed is independent of the size of ship, *i.e.*, it takes, at constant speed, the same power to drive any size of ship. If the horse-power varies faster than the 7th power of the speed, the larger the ship is the smaller is the power required to drive her at any given speed; and if the horse-power varies at a less rate than the 7th power of the speed, the larger the ship is the larger is the power required to drive her at any given speed.

For, according to the law of comparison, the I.H.P. varies as the 3·5th power of the ratio of the linear dimensions. Hence it follows that the I.H.P. varies as the 7th power of the corresponding speeds for varying displacement.

Let *i.h.p.* be the power of the model ship of D tons displacement at V knots speed, and I.H.P._1 the power of the enlarged ship of D_1 tons at V_1 knots speed, then $\frac{\text{I.H.P.}_1}{i.h.p.} = \left(\frac{V_1}{V}\right)^7$. Let now the indicated horse-power required to drive the ship of D_1 tons (that is constant displacement) vary as the nth power of the speed, and it follows if I.H.P. is the power required to drive D_1 tons V knots, that $\frac{\text{I.H.P.}_1}{\text{I.H.P.}} = \left(\frac{V_1}{V}\right)^n$, and consequently, that $\frac{\text{I.H.P.}}{i.h.p.} = \left(\frac{V_1}{V}\right)^{7-n}$. But we also know from the law of comparison that $\frac{V_1}{V} = \left(\frac{D_1}{D}\right)^{\frac{1}{6}}$, and consequently we have the final expression, $\frac{\text{I.H.P.}}{i.h.p.} = \left(\frac{D_1}{D}\right)^{\frac{7-n}{6}}$; *i.e.*, the horse-power varying as the $\frac{7-n}{6}$ power of the displacement at constant speed but for varying displacements.

Now, then, if in this expression n is made equal to 7, implying that for given displacement the power to drive the ship varies as the 7th power of the speed, we get I.H.P. = *i.h.p.*, showing that I.H.P. is constant for all displacements at any given speed, *i.e.*, I.H.P. is independent of the size of ship. If n is made less than 7, the power increases with increase of displacement, and if n is greater than 7, the power decreases with increase of displacement, which is the case when it is possible to drive a larger ship with less power than a smaller one at any given speed. Q.E.D.

Corollary.—If $n = 3$, $\frac{\text{I.H.P.}}{i.h.p.} = \left(\frac{D_1}{D}\right)^{\frac{2}{3}}$, which is the Admiralty displacement co-efficient. If $n = 4$, $\frac{\text{I.H.P.}}{i.h.p.} = \left(\frac{D_1}{D}\right)^{\frac{1}{2}}$, etc. If $n = 2$, $\frac{\text{I.H.P.}}{i.h.p.} = \left(\frac{D_1}{D}\right)^{\frac{5}{6}}$, and if $n = 1$, *i.e.*, if resistance should be constant at all speeds, $\frac{\text{I.H.P.}}{i.h.p.} = \frac{D_1}{D}$, $\because$ varying directly as the displacement. If $n = 13$, $\frac{\text{I.H.P.}}{i.h.p.} = \left(\frac{D_1}{D}\right)^{-1}$, which means that if the resistance to the propulsion of a ship is so great that the indicated horse-power required to drive her varies as the 13th power of the speed, the horse-power at constant speed varies inversely as the displacement, $\because$ it takes for instance in such a case half the power to drive twice the displacement. The expression $\frac{\text{I.H.P.}}{i.h.p.} = \left(\frac{D_1}{D}\right)^{\frac{7-n}{6}}$ therefore shows that the higher the rate of resistance to propulsion for varying speed is, the less is the influence of difference in size at constant speed and *vice versa.*

In practice, at the highest speeds for steamers the I.H.P. may vary as the 7th power of the speed and even at a higher rate, so therefore it is actually possible to drive a larger ship with the same or less power than a smaller one a given speed.

W. Hök.

Mr. G. W. Sivewright said as a shipbuilder he would have liked to have seen some outlines of ships in connection with the curves so that they might have been able to make a better comparison of the ships with regard to dimensions. He thought a paragraph on page 78 wanted further explanation, where Mr. Young stated that "by increasing the displacement they still maintained the same speed but without increasing the indicated horse-power." He had had a similar experience in which they had built a ship 270 feet long with a certain horse-power. The owners afterwards asked them to lengthen the ship amidships by some 20 feet, and they got the same speed out of the increased length as they did with the shorter vessel. From the result he came to the conclusion the shorter ship had too much power, and the longer ship being a much better proportioned vessel explained the seemingly unusual result, and he imagined from the paragraph this was Mr. Young's experience. It would be desirable in comparing curves that they should endeavour to compare vessels with the same cube dimensions, for if this was not done considerable correction

would be required to be made. In explanation of this, there could be no doubt if they had a wide, shallow ship, say of 4,000 tons displacement, and a longer and better proportioned ship of the same displacement, much better results would be obtained from the longer ship. There was another point that was being continually expressed by shipowners and should be taken notice of, this was the statement that a ship could be any dimensions and any shape provided the after-end of the vessel was made fine. He knew from experience this statement was not altogether right, because in a sea-way the fore-end of the vessel if very full was most likely to stop the ship, and this was conclusively proved if a full fore-ended ship was driven into a heavy sea. He wished Mr. Young would continue this paper and give them some curves of cargo boats, he was sure they wanted them all round, and as a shipbuilder, if they could only get shipowners out of building awkward dimensioned ships of the fullest coefficient, the writing of such a paper would serve a very useful purpose. It might be thought in slow cargo boats there was no necessity for speed curves, but he thought this was entirely wrong. During the last few years in increasing the size of vessels they had erred very much in giving them too much beam, and much as a shipowner should endeavour to get a shallow, wide ship for light draught, yet, if he wanted true economy over the lifetime of the vessel, it was absolutely certain that better results would be got out of a well proportioned vessel not too full, than out of the wide beam, shallow draught boats of awkward dimensions. The shipowner would certainly gain a little in saving lighterage by having shallow draught, but the steaming economy of the ship at sea would be ruined. He congratulated Mr. Young on his paper. If it would not be too much trouble would he kindly add as an Appendix a list of some of the most important speed trials that have been made and have appeared in other Transactions, as he was certain it would be of service to the members of this Institution? In preparing a paper like what Mr. Young had written he was sure Mr. Young must have all such data handy for reference.

The PRESIDENT said Mr. Sivewright had plainly put their position so far as experience went of speeds. He was very glad to hear him say that they were building some awkward dimensioned ships at present. He thought it was a point that shipowners had very much neglected. In the address he (the President) gave at the opening of the session any of them who had taken the trouble to look through the particulars given there would find a very low co-efficient of displacement in comparison with the general run of ships being built to-day. He thought it was entirely

owing to taking progressive trials. He had it on the authority not only of one owner but many owners that taking it over a period of a year or two—not a special voyage where special purposes may give a favourable result—but taking a period of years that higher speeds do pay and pay best. This paper by Mr. Young indicated a want at the present time that was felt all-round. They required to know more definitely what amount of cargo they were going to carry, what size of engine they wanted to drive the ship at a given rate of speed. In some ships, he believed with Mr. Sivewright, the engines were too big, in others too small, and that was entirely due to want of knowledge. Owners were very backward in allowing the loan of their boats for two or three hours to run these progressive trials, hence they worked only by theory. That might do for large vessels, but for cargo boats they wanted experience more than theory. Mr. Sivewright said the fore-end stopped the ship more than the after-end, that would apply where there was a higher speed; but he found in his experience that trim had a good deal to do with it. He had found boats put down 2 feet at the stern, showing the drag of wave going at right angles from the ship's quarter, and these were points that could be brought out if they had more practice and speed curves. He for one would be very much pleased in connection with the paper Mr. Young had given them—and it was a departure from the ordinary run of curves they had had—if he created a desire for further information and experiment so as to give them actual knowledge from trials to definitely fix the size of engines. The economy to shipowners would be more than one had any idea of, and would tend to a more economical form of ship, not only to steam well and steer well, but a handier ship altogether. If this were brought about he was sure they would be very thankful to Mr. Young. He thought they were hardly paying a compliment to him, however, not to have more discussion upon his valuable paper.

Mr. W. G. Spence said that he was not prepared to discuss the paper in its academical aspects. He understood the practical application of the method, but was not in a position to analyse the underlying principles on which it was based. Referring to what the President had said about progressive trials, he might add that during the present year the firm of Messrs. George Clark, Limited, had carried out eight load progressive trials with vessels varying from ·75 to ·82 coefficient, judging from these results it seemed to appear that so long as the speed did not exceed 9 to 9½ knots the bluffness of the coefficient had very little effect on good sized boats. Mr. Young's diagram afforded a rapid method of graphically

recording results got from progressive trials, and of applying them to vessels of varying size but similar type. The ordinary method of doing this was a very tedious process, and for this reason he considered Mr. Young's idea a very valuable and ingenious one. Care had, however, to be exercised in applying those results. If the proposed vessel was smaller than the one whose trials had been used as a basis for the curves, they would find the actual horse-power required was greater than that given by the diagram, although the ships were of identical type and the diagram included the effect of corresponding speed due to length. What might be the proportionate amount or exact cause or causes of the difference he was not prepared to say, but it existed, and anyone adopting the method would have to guard against it.

MR. YOUNG'S REPLY.

Mr. YOUNG, in reply to the discussion, said that he felt much indebted to the speakers for their complimentary remarks upon his paper. He would have liked to have had time to treat the subject as fully as some of them had wished. But, then, his paper was not intended to be a full treatise upon the subject of speed curves, but only a description of a graphic application of the laws of ship resistance.

With regard to Mr. Sivewright's question, he thought that Mr. Sivewright had somewhat misunderstood his statement with regard to propelling a large ship at the same speed as a smaller one with the same horse-power. This occurred often when a ship was lengthened, but then the two models were not similar. The statement in the paper was intended to be applied to similar models, that is, models of the same ratio of length to breadth and length to draught, and the same coefficient of displacement and of water-lines.

Mr. Hök had proved this analytically, and Mr. Hök's proof was in entire agreement with the results obtained from the diagram under consideration. Mr. Hök's communication was in that respect a very valuable one indeed. He had referred, however, to the error at high speeds, or, to speak more accurately, at large powers. Well, there was one peculiarity about this graphic method of calculation, viz., that the probable error per cent. was continuous throughout. If the error was ½ per cent. at 100 horse-power, they would have the same error per cent. at 1,000 or at 10,000 horse-power, and there was no difficulty in reading off the scale with that degree of accuracy when fully divided. Also in

speed calculations they usually had to deal with round numbers, and there was not much prospect of their ever having to deal with fractions or even units when large powers were under consideration. Mr. Hök had objected to the distortion of the curve by multiplying the ordinates by a variable. But, then, the variable used was not an irregular one, and, as seen in the curves of the "Edgar" and "Lepanto," all the salient features of the original curve were visible in the new curve. And, besides, a continuous curve was preserved, which is not the case in either the Biles or the Inglis methods.

Referring to the correction required for length, it would be found stated in the paper that this correction was necessary, and that Mr. R. E. Froude had given the necessary corrections in his paper before the Institution of Naval Architects in 1888.

He could not agree with Mr. Hök in thinking high piston speed in fast liners to be due mainly to a desire to lighten engines. The necessity of not deviating greatly from the ordinary proportions of propellers seemed to him to have, in these cases, a marked effect in raising piston speed, even if that necessity were only unconsciously acknowledged.

With regard to the weight of engines in similar ships at corresponding speeds, it could be at once proved that the weight should vary as the $\frac{8}{7}$th power of the I.H.P., but owing to the greater economy of material possible in larger engines this law had not much influence. With reference to the power of the speed at which the I.H.P. increased, this could be found graphically by dividing any horizontal line intercepted between the vertical scale on the left, and the gradient, into seven equal parts, and then radial lines to these points from the terminal point of the scales (marked 1 knot) would show the direction of the curve when it varied as the 1st, 2nd, 3rd, 4th, 5th, 6th, or 7th power of the speed. By prolonging such a power index beyond the gradient higher ratios could be measured.

There were two ways of obviating the error due to shrinkage of material. One was to have both the scale and the curves drawn upon the same kind of material, the other was to mark two known values or spots on the tracing paper, say the extremities of the scales, and allow for the actual shrinkage or expansion that took place.

He thought that they would all agree with the President's remarks about experience with cargo boats, for if there was one type in which experience was more necessary than in any other, he thought it was our full cargo steamers.

He agreed with Mr. Spence's remarks about the apparently small

difference between vessels of certain degrees of fulness, but that was only at very moderate speeds—as they were usually driven at. With regard to the surface friction correction due to length, he referred Mr. Spence to the paper by Mr. R. E. Froude mentioned already.

He had hoped to have had a communication from Mr. J. Johnson upon the subject of the paper, and he might say that it was to Mr. Johnson that he owed his introduction to the question of the laws of similarity.

The Application to Propellers.

It did not seem to have been recognised that the laws of similarity could be applied to similar propellers running at corresponding revolutions and slip. It was simply necessary to substitute a scale of propeller diameter, say, from 3 up to 27 feet, for that of length, as it would be found that when the revolutions varied inversely as the square root of the diameter, the thrust would be proportional to the cube of the diameter and the I.H.P. to the $\frac{7}{2}$nd power of the diameter for given efficiency. But the question was too wide to be treated in such an off-hand way, as it demanded fuller treatment than was possible at the time, and would require a separate paper to do it justice.

The President said he was sure they were very much indebted to Mr. Young for his paper, and as he (Mr. Young) said it would take very little trouble to adapt the curves for propellers they would be still further indebted to him if he would do so. He thought it would be a very beneficial addition to the present curve. He put it to them, that the best thanks of the meeting be given to Mr. Young for the valuable paper he had read.

The proposal was cordially adopted.

APPENDIX B.

List of some Steam Trials.

S.S. "Lepanto"	*Engineering*,	Aug. 24, 1888.
S.Y. "Mazeppa"	"	July 3, 1891.
S.Y. "Oriental"	"	" "
S.Y. "Primrose"	"	" "
Atlantic liners (various)	"	Dec. 4, "
Spanish torpedo boats	"	Mar. 29, 1889.
Sunderland torpedo boat	"	Jan. 10, 1890.
H.M.S. "Edgar"	"	" 15, 1892.
Gunboat "Ceram"	*Industries*,	" 20, 1888.
S.S. "Reaumur" (cargo boat)	*Mechanical World*,	Nov. 15, 1890.

MARINE BOILER FURNACES.

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[Read before the Institution, in Newcastle-upon-Tyne, on December 14th, 1892.]

A boiler furnace is one of the most important details in marine engineering, as it not only represents the most efficient heating surface in the boiler, but in the event of accidents its replacement or repair is highly expensive in itself, and involves the temporary disablement of the steamer.

From the nature of the manufacture and the great expense of experimental tests, engineers generally have had less opportunity of becoming thoroughly conversant with modern furnaces than with any other detail of marine engineering, and the object of this paper is to lay before the Institution the results of some experiments which have been made, and also by advancing certain theories resulting from actual experience to arrive by discussion at the probable cause of the many commercially disastrous accidents of recent years.

The chief points upon which this paper will treat are :—Design, mode of manufacture, practical requirements, strength, and material.

As soon as steam of a higher pressure than that of the atmosphere began to be used it was found desirable to replace the ordinary square section furnace with its flat sides and top by a design theoretically stronger and less liable to collapse under pressure ; consequently the cylindrical form was chosen and, with modifications, still remains in use. When steam pressure of 100 lbs. per square inch and over became general the thickness required for a long plain furnace was excessive, and engineers considered how it was possible to obtain the necessary strength in a more scientific manner than by increasing the thickness of the plate.

Experiments made by Fairbairn had shown that the strength of a flue under collapsing pressure varied with the length, and that short flues were stronger than long ones, so the first step taken to increase the strength

of plain flues was by adding strengthening rings circumferentially, thus practically making one long flue into several short ones. At first angle or T-rings were riveted on, but as the rivets were directly exposed to the fire, a better arrangement, known as Adamson's rings, was ultimately adopted. This design consists of short plain cylindrical tubes, flanged outwards at the ends, so that two rings or more may be conveniently riveted together, the rivets being completely covered by water and so protected from the fire. The method of manufacture of flues constructed with Adamson's rings is so well known that further explanation is unnecessary, and although marine engineers prefer a furnace with no circumferential joints, these furnaces are still fitted in high pressure boilers and various experimental results, which have been kindly placed at the disposal of the writer by Messrs. Hall, Russell & Co., of Aberdeen, and Messrs. J. Howden & Co., of Glasgow, will be referred to subsequently.

A great step forward was the introduction by Mr. Samson Fox of his corrugated furnace flue, the strength of which is so much in excess of that of a plain flue that it came rapidly into use and was for a considerable time almost universally adopted for high pressure boilers; indeed, it is certain that the rapid adoption of the triple expansion engine was due in a great measure to this invention. Corrugated furnaces were first introduced in 1879, the method of manufacture being the crude one of hammering a plain flue on a corrugated anvil block. In 1882 Mr. Samson Fox invented his rolling mill, which is still used by the Leeds Forge Company for the production of both Fox's corrugated and Morison's suspension furnaces, the latter being an improved design lately introduced. These furnaces are made from Siemens-Martin steel ingots rolled into plates of the required dimensions under ordinary plain rolls. Three sides of a plate are sheared, and on the fourth side the development of the saddle is marked and punched out. Test-pieces are taken from the scrap thus produced and tested for tensile, elongation, and bending. The plate is then formed into a tube and lap-welded by water-gas, the welding by this process being so efficient that in a series of tests lately made the tensile strength across the weld was found to be but slightly less than the original plate. This welded tube is next heated in a special furnace and is then placed in Fox's patent mill, the rolls of which are corrugated, and in order to get the tube between the rolls the top roll is worked out and in longitudinally by hydraulic power. Complete corrugations are formed by one revolution, but a few turns are given for finishing, and the furnace is withdrawn as a perfectly cylindrical corrugated tube. Flanging is the next process, and although this has hitherto been done by hand, arrange-

ments are being made for flanging by hydraulic pressure. This undoubtedly will be a great improvement, because of the fact that the greater the amount of work put on the back ends of furnaces of any type, the greater is the liability to crack, especially if the steel is of very high tensile strength. The furnace is now complete, the final process being annealing.

A modification of the "Fox" is that known as the "Farnley" flue, the corrugations of which are similar to those of the Fox, but instead of being at right angles to the axis they form a series of spirals, the advantage claimed being additional longitudinal rigidity.

Another step in the direction of increased practical efficiency is a design by Mr. Holmes, of Hull, the feature in this furnace being that the outward corrugations are pitched about 16 inches from centre to centre, the distance between the corrugations being of plain cylindrical section. In the Holmes furnace the corrugations are 2 inches in depth, and are formed one at a time by pressing the metal between suitable dies, the furnace being revolved between each application of pressure.

The furnace which has been the greatest rival to the Fox is that known as Purves's patent, and is manufactured by Messrs. John Brown & Co., of Sheffield. This furnace was patented in 1880 by Mr. Purves, late of Lloyd's Registry, and consists of a series of thickened ribs 9 inches between centres, the part between the strengthening ribs being of plain cylindrical form. A novelty in this furnace is the method of manufacture, as it is the first furnace of unequal section, and the first furnace not made from an originally plain plate of equal thickness throughout. The "Purves" flue is made from a Siemens-Martin ingot. Rectangular section slabs sufficient for two flues are formed from these ingots under a 15-ton hammer, the slabs being about 7¼ inches thick, and their length being equal approximately to the length of the flues required. Special roughing rolls convert the slab into a ribbed plate 1¼ inches thick, which is then cut in two by very powerful shears, and, after re-heating, each half is passed through finishing rolls until the final required thickness is obtained. At one side edge there is a piece of plain plate 15 inches wide to the centre of the first rib intended for the front end of the flue, and at the other side the plain part is 23 inches wide and intended for the back end of the flue, and the thickness in both these side edges is increased by ⅛th to allow for the thinning which takes place during flanging, etc. After being sheared at the edges and the end slotted to the shape required, the plate is bent into a circular form by a special hydraulic press. The edges are then welded together by the insertion of glut-pieces,

the plain parts being welded first and the ribs afterwards. Annealing is the next process, and after being withdrawn from the furnace the flue is converted into a perfectly circular tube by a very ingenious hydraulic press. It is then flanged, etc., in the ordinary way, the final process being annealing.

The latest design introduced is that known as Morison's suspension furnace, which is a modification of both the Fox and Purves types, and a combination of the good features of each. It is manufactured in exactly the same way as the Fox, the same processes being employed throughout.

An ingenious arrangement (Fig. 15, Plate XXVII.) for facilitating the removal and replacement of furnaces (which are flanged to meet the combustion chamber tube plate) has been devised by Mr. Ashlin, and consists in cutting away the lower half of the flanged end so that it terminates in a plane inclined at about 120 degrees to the horizontal, and consequently the furnace when being removed from the boiler can be raised and tilted at its front end, thus enabling the flanged portion to be withdrawn.

Requirements of a Furnace.

The apparent practical requirements of a furnace suitable for high pressures in modern marine boilers are :—

(*a*) The furnace should be such as to give it the greatest evaporative efficiency and the least mean temperature.

(*b*) The material should be so disposed as to give the greatest resistance to collapse without undue rigidity in a longitudinal direction.

(*c*) The strength of the flue should be uniform throughout its length so as to prevent partial collapse or local sagging.

(*d*) The material should be of equal thickness, so that expanison may be uniform and not unequal and local.

(*e*) The formation should be such that the strains resulting from extreme variations of temperature should be distributed throughout the length of the furnace, and not concentrated at any point so as to induce cracking.

(*f*) There should be no narrow cavities or recesses for undue and unequal accumulation of deposit, resulting in the burning of the material, and also in decreased evaporative efficiency.

(*g*) The strengthening projections should be outwards, or towards the water space, and so protected from the fire.

(*h*) The furnace should be of such formation as can be easily scaled, cleaned, repaired, or replaced.

(*i*) The material of which the furnace is made should be such as has been found by experience to be reliable in manufacture, and the most suitable for withstanding the extreme variations of temperature, rather than such as has the greatest tensile strength. In other words, the material should be of the best quality for standing the comparative rough treatment of the boilershop, and the alternate and repeated heating and cooling of the furnace when in use, and the necessary strength should be obtained by the efficient disposition of material, thus giving suitability of material the first consideration rather than the strength of material.

Before proceeding to consider how the furnaces under notice fulfil the requirements previously enumerated, it should be noted that the minimum steam pressure in a modern marine boiler is 160 lbs. per square inch, and the tendency is to increase that pressure up to 180, and even 200 lbs., and also that a furnace of large diameter with a short grate is more efficient than a small diameter with a long grate; for two reasons —one being that the combustion is more perfect in the larger furnace, and the other, the practical reason, that an average fireman is able to fire a short grate better than a long one, especially in these days of limitation of work and disinclination to exert a maximum amount of energy. These considerations alone seriously detract from the value of the ordinary plain furnace, as, all other conditions being similar, it is the weakest form of cylindrical furnace at present in use; and as the greatest thickness allowed by the Board of Trade is $\frac{5}{8}$ of an inch, the largest diameter obtainable for 180 lbs. with a furnace 6 feet 6 inches long is 27·3 inches, and this is with steel of from 26 to 30 tons tensile.

Lloyd's, however, allow a greater thickness, and some engineers use plain furnaces up to $\frac{3}{4}$ of an inch; but the all-important commercial question is—Do these thick plain furnaces of small diameter result in the maximum obtainable efficiency in a modern steamship? and as the keen competition in shipping demands that for success attention should be given to every detail, it is necessary that a furnace should be not only the most economical for steam producing, but should be of such a formation as will last the greatest length of time and have the least prejudicial effect on the wear and tear of the boiler. The material of a furnace is subjected to greater variations of temperature than in any other part of the boiler, being greatest in amount above the grate bar and least below. Intensity of temperature above the grate bar depends on the condition of the fire, the thickness of the plate, the amount of deposit on the plate, and the

steam pressure. The variations of temperature are incessant, and depend on condition of fires, opening and shutting of doors, and cleaning of fires. These variations of temperature result in expansion and contraction producing definite mechanical movement, and if the design of furnace is such that it cannot readily adapt itself to those movements (and no plain furnace can) either the material becomes distressed, or such strains are produced on the boiler that leakage results. This would appear to be a reason why the corrosion at the firebar level in plain furnaces is often found to be greater than in corrugated furnaces, as in the former case the furnace is rigid, and the material is subjected to more severe strains than in the case of a furnace which has greater elasticity.

The Adamson design is a considerable advance upon the plain furnace, from the fact that it is less rigid in a longitudinal direction and is stronger to resist collapse. It has, however, the objectionable feature of a series of circumferential riveted joints. This defect is removed in the Holmes's furnace, which, although not introduced immediately after the Adamson, is the next step in advance of it.

The Fox furnace at the time of its introduction was the strongest form to resist collapse ever made, whilst the nature of its formation rendered it specially suitable for accommodating itself to the strains resulting from variation of temperature, and the fact that it is of uniform thickness and of uniform design caused the strains to be distributed throughout the length of the furnace. This uniform distribution of strains is the most important feature, as, if these strains are localised, accidents will ultimately result. Theoretically, the Fox furnace approaches perfection; practically, however, it has defects, the chief of which is the undue accumulation of deposit in the narrow cavity formed by the inward corrugations, and as these corrugations are nearest to the fire the material becomes overheated and frequently cracks. The scale in these narrow cavities is also difficult to remove and often but imperfectly removed, thus intensifying the danger of accident. These practical defects of the Fox furnace being generally recognised by engineers was undoubtedly the chief cause of the rapid adoption of the Purves design, in which not only are the supporting ribs in the water space (and so removed from the action of the fire) but there is no cavity for the undue accumulation of scale and no greater expense incurred in scaling than with a plain furnace.

These advantages are obtained, however, at the sacrifice of others, as, all conditions being similar, the Purves flue is not so strong as the Fox to resist collapse, whilst its unequal section and longitudinal rigidity localise the stress resulting from variation of temperature, an evidence

of which is the occasional development of cracks either by circumferential ripping at the base of the rib or in the vicinity of the flanges at the back end, and although this is an accident which is fortunately not common, it is sufficient to show the advantage of uniform distribution of strains. The section of the Purves flue being unequal, and the strength to resist collapse not being uniform, the first sign of collapse is the local sagging or pocketing of the flat parts between the ribs. The furnace, however, has been largely used, and it was the writer's practical experience with it which suggested the design of the suspension furnace, the object of which was to combine those features in the Fox and Purves designs which experience had shown to be necessary for practical success, and to reject those features in each which practice had proved to be bad. The features retained from the Fox design are—the disposition of the material in a form which gives the greatest resistance to collapse, uniform thickness and uniform strength throughout, distribution of strains uniformly throughout the length of the furnace. The features retained from the Purves flue are—the strengthening formations are in the water space and are protected from the fire, there are no narrow cavities for the accumulation of scale, and there are equal facilities for scaling and cleaning.

A feature often claimed for the Fox furnace is additional evaporative efficiency due to additional area of heating surface, but when it is remembered that the current of heated gases impinges on the inward corrugations whilst the recesses formed by the outward corrugations are filled with gas comparatively stagnant, and also when it is remembered that the inward corrugations by receiving the greatest heat produce the greatest thickness of deposit, the efficiency of this additional surface is, in the writer's opinion, often over-estimated. In the Purves design the heated gas sweeps over nearly the whole surface, the only recesses being those formed by the ribs, and the same is practically the case in the Morison furnace. A frequently suggested arrangement is the simple reversal of the latter design, thus making the long suspension curve into an arch, but a little consideration will show that not only would the material forming the inward projections become overheated by the current of hot gas sweeping over the points, but the recesses formed by the arched surface would be filled with eddies of somewhat stagnant gas of a much lower temperature, and there can be little doubt that the evaporative efficiency of such a furnace would be less than a plain furnace of equal thickness.

A design which has been patented and re-patented is a furnace of barrel shape, either of equal thickness throughout or of varying thickness.

The most successful furnace of this type at present being manufactured is that of Messrs. W. Arnold & Co., of Barnsley, and consists of a series of flanged barrel-shaped sections. This form is not suitable for marine work; and another design which has been proposed, consisting of a single length of barrel-shaped tube, would be still less so, and would be a very weak form of furnace.

There has been a host of other designs evidently patented with a view of evading recognised successful manufactures and without any idea whatever of actual improvement, but naturally none of these have been adopted.

Strength to Resist Collapse.

The first experiments upon the collapsing strength of plain cylindrical tubes were those by Fairbairn, but as the greater number of these were made upon cylinders of small diameter it is very doubtful whether the results obtained apply to flues of the dimensions in modern practice. Fairbairn's experiments have, however, been accepted by the majority of engineers as reliable, and the formula deduced therefrom has formed the basis of all rules for the strength of plain cylindrical flues. Fairbairn's formula was:—

$$P = \frac{806{,}300 \times K^2}{L \times D},$$

where P = the collapsing pressure in lbs. per square inch.
K = thickness of the plate in inches.
L = length of the flue in feet.
D = diameter of the flue in inches.

This implies that the strength of a flue to resist collapse varies inversely as its length, and directly as the square of the thickness; but the latter may be questioned when the flue is of the proportions necessary for marine boilers. Both the Board of Trade and Lloyd's have adopted this formula with an alteration of the constants.

Board of Trade (steel furnaces):—

$$\text{Working pressure per square inch} = \frac{99{,}000 \times K^2}{(\text{length in feet} + 1) \times D}.$$

Lloyd's Register:—

$$\text{Working pressure in lbs. per square inch} = \frac{89{,}600 \times K^2}{L \times D}.$$

Although there is a limitation in both cases that the pressure must not exceed

$$\frac{8{,}800 \times T}{D} \text{ for the Board of Trade,}$$

$$\text{or } \frac{8{,}000 \times T}{D} \text{ for Lloyd's,}$$

which shows its empirical nature.

Valuable experiments on Adamson's rings were conducted by Messrs. Hall, Russell & Co., of Aberdeen, in 1882, and by Messrs. J. Howden & Co., of Glasgow, in 1887.

In Messrs. Hall, Russell & Co.'s experiment (see Fig. 1, Plate XVII.) only one of the rings was collapsed, and after it had been temporarily strengthened the experiment was again proceeded with. Unfortunately, when the pressure was raised about 40 lbs. above that at which the ring had collapsed, the outer cylinder burst and the experiment was abandoned. The coefficient given by the collapsed ring was:—

$$\frac{P \times D}{T} = 64{,}213,$$

the diameter being taken over the plain part, and on careful measurement the collapsed ring was found to be of less thickness than any of the others.

Messrs. J. Howden & Co. experimented upon a furnace formed with four rings, each 23 inches long, and after each ring collapsed it was strengthened and the pressure still further increased until all the rings had been collapsed. Detailed particulars are given in Table I., page 132, the collapsing coefficient being 64,240, which agrees remarkably well with the results obtained by Messrs. Hall, Russell & Co., although it should be noted that the length of the rings in Messrs. Howden's experiment was 23 inches, and that of Messrs. Hall, Russell & Co. only 19 inches. A section of the flanges of the rings is shown in Fig. 2, Plate XVIII.

There is no actual record available of the mechanical tests of the steel from which these furnaces were made, but they are understood to have been of the ordinary boiler quality manufactured at that time, and from 26 to 30 tons tensile.

The rule adopted by Lloyd's for furnaces made with Adamson's rings, with steel from 26 to 30 tons tensile, is:—

$$\text{Working pressure in lbs. per square inch} = \frac{1{,}000 \times (T - 2)}{D},$$

and by the Board of Trade for steel from 26 to 30 tons:—

$$\frac{8{,}800 \times T}{3 \times D}\left(5 - \frac{L + 12}{67{\cdot}5 \times T}\right) = \text{working pressure in lbs. per square inch,}$$

where

T = thickness of plate in inches (Board of Trade), in sixteenths of an inch (Lloyd's).

L = length of distance between centres of flanges in inches.

D = diameter of furnace in inches outside the flats.

Table II., page 133, gives the tests of the Fox furnace in 1882 and 1891.

In November, 1882, the first test was made upon a single tube of very mild steel, having a tensile strength of 22·7 tons per square inch. Until 1890, all the furnaces were made of this low tensile steel, and the results obtained as compared with the furnaces made of the higher tensile, show, in the writer's opinion, that the step, however necessary from a commercial and competitive point of view, has not been so successful in practice.

This test furnace was 6 feet 9 inches in length by 3 feet 1⅞ inches outside diameter, and had thirteen corrugations 2 inches deep from outside to inside, pitched 6 inches from centre to centre. The furnace was enclosed in a steel cylinder, specially made for the purpose, and connected to it by rivets, as shown in Fig. 3, Plate XIX. Two Dewrance's gauges were used to determine the pressure in the space between the furnace tube and the testing cylinder, the space being filled with water, and the requisite pressure applied by means of a force pump. Before any pressure was applied the furnace was carefully gauged, and is reported to have been truly cylindrical throughout its whole length.

In considering the results of this test, however, it should be remembered that the manufacture was practically in its infancy, and not nearly the same care was then exercised either in the manufacture or the method of recording the tests; consequently it may be safely assumed that if a Fox furnace made of the same steel were tested now the results would be better. For example, measurements were only taken at three points throughout the length of the flue, and it is recorded to have been absolutely cylindrical, although no other furnace experimented upon since has been so accurate. At each increment of 100 lbs. per square inch the furnace was gauged so that under various pressures the limit of elasticity and the ultimate strength to resist collapse should be ascertained. Up to 500 lbs. per square inch no alteration in the cylindrical form of the furnace was perceptible; at 800 lbs. it had altered its form to the extent of $\frac{1}{32}$nd of an inch, but on the pressure being released it entirely recovered its original shape; permanent set could be distinctly measured at 850 lbs., and at a pressure of 900 it slowly collapsed, altering its form more readily than could be followed up by the pump. After collapse twelve holes were drilled in the furnace, and the thickness was found to vary from ·51 to ·53 of an inch.

It should be noted that until recently the Board of Trade took the mean diameter, viz., the mean between the least internal and greatest external. Lloyd's, however, take the greatest external, but for comparison

of results given in this paper the diameter taken for the strength coefficient will be the mean diameter for furnaces of the Fox, Morison, and Farnley types, and the least external diameter for the Adamson, Holmes, and Purves designs.

The collapsing coefficent given by the test is :—

$$\frac{900 \times 35{\cdot}875}{52} = 62{,}091,$$

and the formula adopted by the Board of Trade for steel under 26 tons tensile, as a result of the experiment, was:—

$$\frac{12{,}500 \times \text{thickness in inches}}{\text{mean diameter in inches}} = \text{working pressure in lbs. per square inch,}$$

and by Lloyd's for the same limit :—

$$\frac{1{,}000\ (T - 2)}{D} = \text{working pressure in lbs. per square inch.}$$

Where T is the thickness of the plate in sixteenths of an inch and D the greatest diameter of the furnace in inches.

The Board of Trade formula gives a working pressure of 181·2 for the above furnace, and Lloyd's a working pressure of 166·8, so that on a basis of 22·7 tensile the factor of safety by Board of Trade rules was 4·97, and by Lloyd's 5·39. These factors are important as they were the first granted for a modern furnace, and the experiment forms the basis of all subsequent tests, although now six furnaces are demanded for testing to destruction instead of one, and the severity of the requirements and the exactness of the tests are apparently increasing with each series. A higher value was granted by the Board of Trade than by Lloyd's for this furnace, but that the former was a perfectly safe allowance has been fully proved by experience, and will be referred to subsequently. From November, 1882, until 1890, the Fox furnace was made of steel between 22 and 26 tons tensile, but in the latter year it became necessary for commercial reasons to adopt a harder steel with a view of obtaining a higher coefficient than that which had been in successful use during the previous eight years. Accordingly six furnaces were prepared and tested between the 4th November, 1890, and the 11th February, 1891.

Full particulars of these furnaces are given in Table II.; the pitch and depth of the corrugations were the same as in the first test, the radical difference being that the steel employed had a mean tensile strength of 29·07 tons as against 22·7 for the first test. The second furnace of this series is said to have collapsed at the 6 inch plain part where the thickness was only ·331 of an inch, the mean thickness being ·378. For this reason it has been proposed to abandon this test and take

a mean of the other five, but as these furnaces were presumably made for purposes of experiment at least as much care would be exercised in their manufacture as in those intended for sale, and therefore little injustice would be done by including this test with the others. Of the six furnaces tested three collapsed on the plain part at the ends, one collapsed on the end corrugation, and the other two on the second and eleventh corrugations.

The mean collapsing coefficient from the six tests is 80,931, the difference between 62,091 and 80,931 being principally due to the increased strength of the steel as may be seen by simple proportion:—

$$\frac{62{,}091 \times 29{\cdot}07}{22{\cdot}7} = 79{,}514,$$

and when it is remembered that these flues were made with a degree of accuracy resulting from an experience of eight years, and allowing a margin for the imperfections of the 1882 test, it is evident that the strength of corrugated furnaces under cold water pressure varies directly as the tensile strength of the steel from which they are made.

Five tests of the Farnley flue were made under the Board of Trade in May, 1888, the results of which are given in Table III., page 134, the record of these tests is not quite so complete as many of the others, the steel being, it is understood, of ordinary boiler quality is assumed to have had a tensile strength of 28 tons per square inch, and the mean collapsing coefficient when reduced to 27 tons has a value of 55,122, which is lower than that obtained with Adamson's rings. It should, however, be noted that the Farnley Iron Company have now improved their method of manufacture, and can make furnaces much more truly round and therefore much stronger than when these experiments were made. A perspective view of the Farnley furnace is given in Fig. 5, Plate XXI.

Table IV., page 135, gives the test results of the Holmes design (see Fig. 6, Plate XXII., and Fig. 7, Plate XXIV.). Two of these flues collapsed at the plain part between two corrugations, and in the other case a corrugation and the adjacent plain collapsed. The mean collapsing coefficient given by the three tests is 60,995, and the mean tensile of the steel was 27·2 tons per square inch.

Messrs. John Brown & Co. made the first Board of Trade test with the Purves flue in March, 1886. Two flues were tested, each nominally $\frac{9}{16}$ths thick and 6 feet $6\frac{5}{8}$ inches long between the centres of the inner row of rivets by which it was secured to the angle iron bars. There were seven ribs with a pitch of 9 inches, and the two end ribs were $8\frac{11}{16}$ and $15\frac{11}{16}$ inches respectively from the centres of the inner row of rivets. The end flats were unusually long, and were in fact the weakest part of the flue.

Each rib projected 1 inch above the level of the plate on the outside; the plate was grooved on the inside to a depth nearly equal to the thickness of the plate. The greatest deviation of the first tube from the circular form was $\frac{7}{32}$ of an inch, and of the second tube $\frac{11}{32}$ of an inch. Collapse took place with the first tube at 740 lbs. on the $15\frac{11}{16}$ plain part about 18 inches from the weld, the second tube collapsing at 760 lbs., also at the long flat in the front end, and about 24 inches from the weld. Measurements were taken at twelve test holes in each case, and the thickness was found to be ·568 in the first and ·546 in the second.

Taking the external diameter of the flats as being the diameter acted upon by the water the collapsing coefficients are :—

$$\frac{740 \times 38{\cdot}61}{{\cdot}568} = 50{,}302;$$

$$\frac{760 \times 38{\cdot}685}{{\cdot}546} = 53{,}847;$$

or a mean of 52,074. The mean tensile strength of the material unannealed was 26·9 tons, and as this result was much inferior to that obtained by Messrs. Hall, Russell & Co. and Jas. Howden & Co. with Adamson rings, and as these flues were somewhat roughly made Messrs. John Brown & Co. arranged another series of tests.

Of this second series two furnaces were nominally $\frac{5}{16}$ths, two $\frac{7}{16}$ths, and two $\frac{9}{16}$ths thick. Each of the $\frac{7}{16}$ths and $\frac{9}{16}$ths flues were made from a plate which had been rolled to the form and thickness required, but the $\frac{5}{16}$th tubes were made from plates rolled similar to the $\frac{9}{16}$th and afterwards planed on the ribbed side to the required thickness. Each tube was 6 feet $7\frac{1}{2}$ inches in length between the centres of the inner rows of rivets, and there were eight stiffening ribs pitched 9 inches apart. The centres of the two outer ribs were $6\frac{3}{4}$ and $9\frac{3}{4}$ inches respectively from the centres of the inner rows of rivets in the end rings; the ribs projected about $1\frac{5}{16}$ inches above the outer surface of the tubes, and were grooved to a depth of about $\frac{3}{4}$ inch, as shown in Figs. 9, 10, 11, Plate XXV., and Fig. 12, Plate XXIV., the various results of the tests being given in Table V., page 136. A section of the furnace in position in the test tube is also given in Fig. 8, Plate XXIII.

A point to be noted in this second series of tests of the Purves flue is the rapid reduction of the collapsing coefficients as the thickness of the flue increases; thus, the mean collapsing coefficients for $\frac{5}{16}$ inch, $\frac{7}{16}$ inch, and $\frac{9}{16}$ inch were respectively 81,980, 58,327, and 55,435. The chief cause of this reduction in strength is that the amount of metal in the strengthening ribs is practically a constant quantity, and therefore bears a less proportion to the total in thick flues than in thin.

Comparing the results obtained from the $\frac{9}{16}$th furnace in the second series of tests with the results obtained from the same thickness in the first set, the collapsing coefficients are respectively 55,435 and 52,074. The slight gain, amounting to about 6½ per cent., may be due to the increased tensile strength of the steel (27·9 against 26·9) to the shorter flats at the ends, or to the increased depth of the strengthening ribs. These causes are sufficient to account for a greater increase of strength than was actually obtained, and it is probable that had the $\frac{7}{16}$th and $\frac{9}{16}$th furnaces been more satisfactory in form, a higher collapsing coefficient would have been obtained.

As it is very seldom that $\frac{5}{16}$th furnace flues are used in practice the results of this thickness being so much in excess of the others should be neglected, and the mean of the $\frac{7}{16}$th and $\frac{9}{16}$th taken as representing the strength of flues in actual use for marine boilers. The mean of these four tests is 56,881, which is still considerably under the coefficient obtained with Adamson's rings.

Messrs. John Brown & Co. being still dissatisfied prepared another set of furnaces, which were tested in the same manner in 1889 by the Board of Trade only, and one furnace which was tested by Lloyd's in December, 1890. The results of these tests were much better, and are given in Table VI., page 137. The mean tensile of the steel used in the manufacture of these furnaces is given at 28·2 tons per square inch.

In September and November, 1891, experiments were made by the Leeds Forge Company upon six of Morison's suspension furnaces, the results of which are given in Table VII., page 138. These furnaces were made of steel having a mean tensile strength of 27·17 tons per square inch, and as will be seen from the table the results obtained were remarkably uniform, and may be considered absolutely reliable, as the severity of the Board of Trade requirements, the strict supervision of the entire process of manufacture, including the annealing of the furnaces prior to being riveted in the test tubes, were all carried out with a degree of exactness never exceeded. Of the six furnaces tested, two collapsed on the end flats, and the remaining four on the corrugations; the mean length of flat was 4¾ inches, and as it is not necessary that the corrugations should be alternated in a boiler no longer flat than this need ever be used in practice.

The average collapsing coefficient given by the six furnaces is 82,185, which is slightly higher than that given by the Fox flues, which were made of 29·07 ton steel. Reducing both to a basis of 27 tons we have:—

Morison's collapsing coefficient	...	...	81,641
Fox's " "	...	...	75,153

showing Morison's tests to have given a result 8½ per cent. better than Fox's. The depth of the corrugations for these test furnaces was 2 inches, but as it was considered necessary that the body of a furnace should be the strongest part the rolls were cut ⅛th deeper, so the furnaces as since made are stronger than those tested. Fig. 13, Plate XXVI., shows Morison's furnace and test tube in section, and Fig. 14, Plate XX., gives a full-size section of the corrugations.

Fig. 18, Plate XXX., shows the collapsing coefficients of the furnaces mentioned in this paper, the coefficients being calculated by the formula :—

$$\frac{P \times D}{T} = \text{collapsing coefficient.}$$

The diameter D being the mean diameter in the cases of the Fox, Farnley, and Morison furnaces, and the least external diameter for the Purves, Holmes, and Adamson. The coefficients so found have been brought to the common basis of steel of 27 tons tensile strength so that they may be directly compared. As two furnaces of each thickness were tested in most cases the mean has been taken, and the points in the diagram show the position of these means.

The abscissæ show the thickness of the test furnaces and the ordinates represent the collapsing coefficients. The furnaces in practical use being generally of greater thickness than $\frac{7}{16}$ths, the furnaces under this thickness are shown in the diagram by a dotted line.

The tests of the suspension furnace are remarkably uniform, being represented by an almost horizontal line, thus indicating that the strength of each thickness of furnace is exactly proportional to the thickness of the plate. The low position of the $\frac{5}{16}$th Fox furnace may be ascribed to the fact that it was thin at one end, while the drooping line of the Purves tests shows the influence of the strengthening rib which is greater in thin furnaces than in thicker ones.

It would seem that the Farnley and Holmes tests had not been so accurately carried out as the others, both as regards the manufacture of the furnaces or the method of testing, or the tests would probably have been more uniform.

Flats on Furnace Ends.

The test value of modern marine furnaces depends to an extent on the length of the flat parts at the ends. Fig. 23, Plate XXXV., gives the results of those test furnaces which collapsed at the end flats, the collapsing coefficients having been calculated by taking the external diameter.

Where $$\frac{P \times D}{T} = \text{collapsing coefficient.}$$

P = pressure per square inch at which collapse took place.
D = external diameter of the flat.
T = thickness of flat in inches.

In each case the collapsing coefficient has been reduced to a basis of steel having a tensile strength per square inch of 27 tons. The diagram includes all the Fox, Purves, and Morison test furnaces which collapsed on the flat, the diagonal line representing the mean result.

In the Morison furnace no flat need exceed $4\frac{3}{4}$ inches, and the Board of Trade have fixed the limit at 5 inches, or 1 inch less than in the Fox, the explanation of this difference being that the design of the former is more suitable for short flats than the latter. By the aid of the diagram the collapsing coefficient of any length of flat can be found with any furnace of the modern types. Neglecting the irregularities of the tests, which may be due to one furnace being more nearly circular than another, it is seen that the strength of an end flat bears an inverse ratio to its length. The weakest flat is at the top back end over the bridge, but this in practice can be reduced to a minimum. Flats at the front end and the bottom back end are not exposed to such a high temperature, consequently the end plates in a furnace when in use are probably stronger than that part of the body of a furnace exposed to the greatest heat.

It has lately been the custom when the flat at the back bottom end exceeds the regulation limits to roll in a corrugation half-way round in a Fox furnace, and hammer out a rib half-way round in a Purves design, but unless the flat is very long this appears unnecessary, as deformation or collapse does not generally take place in the ash-pit, except when the furnace is too rigidly stayed.

Factors of Safety.

The furnace manufacture for the mercantile marine of this country is under the absolute control of the Board of Trade and Lloyd's Registry, as not only do these authorities determine the limits of the tensile strength of the steel to be used, but by formulating rules for the strength of furnaces they also control the weight and consequently the commercial value of every type of furnace used in marine boilers.

The importance of the furnace manufacture may be estimated from the fact that the Leeds Forge Company have made over 30,000 corrugated furnaces, while Messrs John Brown & Co., of Sheffield, have made 10,000 of the Purves design. Until recent years, or since the general adoption of triple expansion engines, the types of special furnaces were

but few, the demand for improvement, however, has resulted in other designs, and the increasing severity and accuracy of the Board of Trade tests may be explained by the desire to give each design proportionate value. A tabulated report of the tests of the suspension furnace is appended, which illustrates the highly expensive and thorough nature of the experiments. Table VIII., pages 140 and 141, gives the apparent factors of safety allowed by the Board of Trade and Lloyd's for the various furnaces mentioned in this paper; it also gives the factors reduced to a common basis of steel of 27 tons tensile per square inch. The factors of safety have been formed by dividing the actual collapsing pressures under cold water test by the working pressures allowed by the Board of Trade and Lloyd's rules.

$$\text{Factor of safety} = \frac{\text{actual collapsing pressure}}{\text{pressure given by formula}}.$$

The fluctuations of the factors of safety required at different times for the same furnace, and at the same time for different furnaces, are shown by Fig. 19, Plate XXXI. In 1891 the Board of Trade required a factor for the Fox furnace of 5·58, and in 1892 it is 5·44. For the Purves furnace the factor in 1888 was 4·87, and in 1890 it was 5·05, whilst the Morison furnace has a provisional factor of 5·91.

Lloyd's factors also vary considerably. In 1891 the Fox factor was 5·35, and in 1892 it was 5·24. The factor of the Purves furnace in 1888 was only 4·21; in 1889, 4·21, and in 1890, 4·85. The Holmes furnace requires 5·34; the Farnley 5·39, and the suspension 5·58.

These furnaces being all of high tensile steel cannot be directly compared with the first of the Fox furnace in 1882. The larger factors now demanded seem to indicate a decrease of confidence in steel of the high tensile strength, such as has lately been used. The Board of Trade have now adopted the standard dimension of the least external diameter as a basis for their formula for all furnaces, and as the least internal diameter is a measure of the effective width of grate this dimension seems very suitable and convenient. Lloyd's formulæ require in the case of the Fox, Farnley, and Morison furnaces the greatest external diameter, and for the Purves, Holmes, and Adamson the least external diameter. This difference causes a difficulty in directly comparing the constants allowed for different furnaces, and a standard dimension of the least external diameter would be a great improvement.

Material.

It is impossible to over-estimate the value of determining the quality of steel most suitable for the manufacture of boiler furnace tubes of modern high pressure boilers as suitability of material is the

first essential to practical success. On the introduction of the corrugated furnace in 1882, the manufacturers considered that a steel of low tensile and high elongation was the best for the general requirements of a furnace, and the fact that at the Leeds Forge alone 28,000 furnaces have been made of steel under 26 tons tensile, and that in 1888 the Engineer-in-Chief of the Board of Trade should have written the following in his work on *Boiler Construction*, is a sufficient proof that their views were correct. Mr. Traill says:—"Up to this time (1888) it is not known that any serious casualty has resulted from the collapse of a corrugated furnace, although some have come down, but when this has been the case the plates, it is believed, have been overheated, due to dirt or other easily assigned cause not attributable to defects in the furnace, and such deformations as have taken place would have been of a much more serious nature had the furnace been plain instead of corrugated." Mr. Traill also foreshadows a modification of the Fox design, such as the suspension furnace, as he says, "there is still a good deal of vitality in the corrugated furnace, and possibly its special advantages may yet be improved upon, and so give it new life to compete successfully with any that may come into the market against it." The Board of Trade regulations for furnace steel are that it should not be less than 26 tons tensile strength and should not exceed 30 tons, and recognise 28 tons per square inch with an elongation of not less than 20 per cent. in 10 inches as a good tensile strength such as is suitable for furnaces. Lloyd's also recognise steel of from 26 to 30 tons as suitable for furnaces. The English Admiralty, whose experience with corrugated furnaces of low tensile has been remarkably successful, now specify that the tensile strength of steel for furnaces must not exceed 25 tons with an elongation of not less than 27 per cent. in 8 inches. All Continental Governments also use steel under 26 tons for furnaces, and the U.S. Government requires the tensile to be from 50,000 to 60,000 lbs. or 22·3 to 26·8 tons per square inch. The tensile of the Purves flue has always been from 26 to 30 tons for the mercantile marine, consequently, from a commercial point of view, the Leeds Forge Company were compelled to raise their standard tensile, and since 1890 practically all furnaces for the mercantile marine have been made of steel, having an average tensile of 28 tons, or 4 tons higher than the standard adopted by the Leeds Forge Company prior to that date, and 4 tons higher than the requirements of the English and foreign Governments. The all-important question is, therefore, have furnaces made from steel of from 26 to 30 tons tensile been as successful as those made from 23 to 26 tons? The writer has lately consulted with many

eminent engineers on this important subject, and the general opinion undoubtedly is that we may pay too dearly for the lighter furnaces of the harder material, and the fact that the percentage of failures is now greater than ever before has caused a feeling in favour of softer material, or, in other words, that steel having a tensile strength not exceeding 26 tons with an elongation of 25 per cent. in 8 inches is more suitable for furnaces than steel having a tensile strength not exceeding 30 tons. The advantages for the lower standard are, in the writer's opinion :—

It is better able to stand the rough usage of an ordinary boiler shop.

It is less liable to develop small cracks in manufacture which may pass unnoticed and afterwards extend.

It is more ductile and will stand the continued expansion and contraction incidental to a steam boiler better than high tensile.

It will remain longer ductile than the harder steel

It will also be less liable to crack at the back ends.

In fact, the only point which is apparently in favour of the high tensile is that the first cost of the furnace is slightly less, although the result is uncertainty of material and the probable shortened life of the furnace.

Temperature.

The influence of temperature upon the strength and ductility of mild steel does not seem to have had the attention that the subject merits. There is considerable uncertainty as to the exact temperature of the material of a furnace under actual working condition; but the experiments made by the late Dr. A. C. Kirk throw some light on the subject. (See *Engineering*, 15th July and 9th September, 1892.)

Dr. Kirk aimed at finding the temperature of the fire side of tube plates of various thickness, the upper sides of which were covered with water, which was allowed to boil at atmospheric pressure. The results of the experiments are shown graphically in Fig. 24, Plate XXXVI., the abscissæ representing thickness of tube plate and the ordinates the temperature of the fire side of the plate above 212 degs. Fah. A fair curve is drawn through the mean of the results.

With a clean plate 1 inch thick the temperature of the fire side was found to exceed that of the water side by 294 degs. Fah., while with ½ inch plate the difference under the same conditions was only 88 degs. Fah.

With a temperature on the water side of 380 degs. Fah. corresponding to a steam pressure of 180 lbs. per square inch, the temperature on the fire side of an inch plate would be 670 degrees, and with a ½ inch plate 468 degs. Fah., the conditions being similar to Dr. Kirk's.

The diagram shows that the difference in temperature increases from 88 degs. Fah. with a ½ inch plate to 588 degs. Fah. with a 2¾ inches plate.

It may be noted that the results are not so reliable for very thick plates, but within the limits of thickness used in practice they give an approximate indication of the temperatures.

The thickness of the plate of which a furnace is formed has a direct influence upon the temperature of the material of the furnace, and as the limits vary between ½ inch and 1 inch, and also as in actual use a furnace has always more or less scale, it may be assumed that the temperature of the material of an average furnace, while in use at sea and with a boiler-pressure of 180 lbs. per square inch, will approach the temperature as found by Dr. Kirk's experiment, viz., between 468 degs. and 670 degs. Fah.

The influence of temperature upon the behaviour of mild steel under tension is shown by a splendid set of experiments made with the United States testing machine in 1888, from which the diagrams, Plates XXXII., XXXIII., and XXXIV., have been copied.

Briefly, the results shown by these experiments are—that the tensile strength of all steel decreases from zero Fah. to a temperature of 200 degs. to 300 degs. Fah.; this is followed by an increase, and the maximum tensile strength is reached at about 400 to 600 degs. Fah.; beyond this latter temperature the strength decreases rapidly.

Although the ultimate tensile strength of the steel increases between 200 degs. and 600 degs. Fah., the elastic limit steadily decreases from zero Fah. upwards, and steel having an elastic limit of 35,000 lbs. per square inch at zero has its elastic limit reduced to 20,000 lbs. per square inch at 600 degs. Fah.

It is also found that between zero and 550 degs. Fah. all steels show decided yielding at loads below the elastic limit, and that after this yielding takes place it may go on even with slightly reduced loads. This is especially the case with mild steels, such as are used for the manufacture of furnaces.

Another point is, that the higher carbon steels reach the temperature of maximum strength more abruptly, and retain their highest strength over a less range of temperature than steels having a low percentage of carbon.

The ductility of steel also varies with the temperature; this is shown by Plate XXXIV., which represents the contraction of area at the point of fracture for various temperatures. There is a tendency to fracture with less contraction of area up to a temperature of 400 degs. to 600 degs. Fah.

In the vicinity of this range of temperature a number of the bars fractured obliquely across their stems instead of at right angles as at higher and lower temperatures. This behaviour is significant, and appears to connect the tensile tests with the brittleness which is also observed in bending tests at these temperatures.

The influence of temperature upon steel may be summarised as follows :—

With a thick furnace the temperature of the plate will be higher than with a thin one, and consequently the elastic limit will be lower, and there will be a liability to sag unless the factor of safety is very high in the first instance.

With thin plates, say about ½ inch to ¾ths thick and 180 lbs. pressure of steam, the temperature of the plate approaches the brittle temperature of steel; it is therefore necessary to guard against this brittleness by employing steel of low tensile strength, as the lower carbon steels retain their maximum strength and ductility over a greater range of temperature than the higher carbon steels.

Longitudinal Elasticity of Furnaces.

The following particulars are extracted from a paper recently read in Germany by Herr Von Knaudt, of the firm of Schulz, Knaudt & Co., of Essen, on "Experiments made to Determine the Longitudinal Elasticity of various Designs of Furnaces." These experiments were evidently made at great cost, and their completeness and reliability form a most valuable addition to furnace literature. The experimental apparatus consisted of a hydraulic press (shown in Plate XXVIII.), in which the furnace to be tested was placed horizontally between the body of the press and the hydraulic ram, these two representing the ends of a boiler. The load was applied longitudinally in increments of 15 lbs., each increment on the pump representing 20·28 tons on the ram. On the completion of each increment the shortening of the furnace was measured, the pressure was taken off, and the length again measured in order to ascertain the permanent set, if any. At intervals the pressure was allowed to remain on for a time, then released, and again applied, but there was practically no difference in the results if no permanent set had taken place. The results of these experiments are shown on Plate XXIX., the horizontal scale representing the load in tons applied to the ends of the furnace, and the vertical scale represents in decimals of an inch, the compression of the furnace in a length of 36 inches. In the curves the full lines denote the results under pressure, and the dotted lines the results after the pressure

was released. The furnaces experimented on were five of the corrugated type, one Adamson and one Purves ribbed. All these were made by Messrs. Schulz, Knaudt & Co., of Essen, with the exception of the Purves flue, which was manufactured by Messrs. John Brown & Co., Sheffield. The tensile strength of the steel for four of the corrugated furnaces, Nos. 1, 3, 4, and 5 on the diagram, and also the Adamson No. 6, was between 21 and 25·4 tons per square inch, with an elongation of 25 to 30 per cent., and the fifth corrugated, or No. 2, was 29·2 tons tensile and 28 per cent. elongation.

The tensile strength of the plate from which the Purves flue was made was not ascertained, but was probably between 26 and 30 tons. Full particulars of the dimensions of each furnace are given on Plate XXVIII. For the comparison of the results take a uniform pressure of 100 tons applied at the end of the furnace. In the corrugated furnaces the compressions were ·134, ·112, ·093, ·075 inch per 36 inches in length, in the Adamson ·021, and in the Purves ·0071 inch. Further, the pressures required to shorten these furnaces $\frac{1}{32}$ of an inch (or ·03125) per 36 inches in length would be for Nos. 1, 2, 3, and 4; 19·27, 24·74, 30·73, and 41·84 tons respectively; No. 5, 92·18; No. 6, 145·22; whilst to compress No. 7 would take 300 tons.

Accidents to furnaces generally result from collapse; the development of small cracks along the line of fire; circumferential ripping in the body of the furnace; and the ripping at the back ends, usually starting from the flanged corners. Neglecting shortness of water, collapse of furnaces is generally due to accumulation, either of scale or of oily deposit, and may be prevented by the use of evaporators and feed-water filters. The development of small cracks along the line of fire is caused by local overheating of the materials due to undue accumulation of deposit. The inward projections of the Fox furnace, for example, are towards the fire, and by receiving the greatest heat cause an undue accumulation of scale in the narrow pocket or cavity formed by the inward corrugation, with the result that the crowns of the corrugations get overheated and sometimes crack. These cracks also occur in the Purves, but generally on or near to the thickened ribs. The most serious form of cracking, however, is the sudden and unexpected ripping of a furnace, either circumferentially in the body or at the back end, these cracks sometimes extending for 18 inches, and completely destroying the furnace. This form of accident can, in the writer's opinion, be avoided by the design and manufacture of the furnace, the disposition of the stays and the suitability of material. It should never be lost sight of when designing the flanged end of a furnace that, the greater work put upon the material during its manu-

facture the greater is the danger of ultimate failure by cracking. It is also known that certain movements of the furnace result from expansion and contraction, consequently if these movements are concentrated at points and not distributed uniformly over the length of the furnace, then if the furnace cracks it will be at the weakest point of concentration. Accidents of this nature may also be caused by the leakage of feed-circulating devices fixed in the boiler bottom. The disposition of stays also appears of importance, as a furnace must and will move; consequently, if the tubes are kept too low, the saddle short, or the furnace stayed in all directions, with stays arranged very near to the surface of the furnace, the very feature of the utmost value, viz., longitudinal elasticity is entirely neutralised. If it is desired to surround a furnace with stays they should, in the writer's opinion, be a slack fit longitudinally. Regarding material, it has been seen that high tensile steel does not remain ductile so long as low tensile; also, that the tensile when under working conditions is greater than when cold; further, at the temperature of working condition the steel is at the point of uncertainty, or the point of the greatest brittleness, consequently the writer would again say that steel not exceeding 26 tons tensile strength is more suitable for furnaces than steel not exceeding 30 tons.

It is also certain that the highest quality of steel of any tensile cannot be obtained without the use of the best materials, and excess of phosphorus and sulphur should never be present in steel which has to be subjected to such severe treatment as in a furnace. The design of flanged corners of the saddle and also the radius between the saddle and the furnace would also seem to effect the ultimate result. If uniform elasticity of design is essential to ultimate success, then these curves should be easy and not sharp and abrupt. These are all practical questions, however, upon which a broad discussion will be of the utmost value.

In conclusion, the writer desires to thank the various firms who have placed data at his disposal, viz., Messrs. T. Richardson & Sons, of Hartlepool; the Leeds Forge Company, of Leeds; Messrs. John Brown & Co., of Sheffield; the Farnley Iron Company, of Leeds; Messrs. Howden & Co., of Glasgow; Messrs. Charles D. Holmes & Co., of Hull; and Messrs. Hall, Russell & Co., of Aberdeen. The paper by Herr Von Knaudt, of Essen, has also supplied the valuable experiment in the longitudinal elasticity, and the temperature tests by the United States Government are certainly the most accurate and most valuable ever compiled, and reflect the greatest possible credit on the officials by whom they were made.

TABLE I.—FURNACES MADE WITH ADAMSON JOINTS.

TESTS MADE AT THE WORKS OF MESSRS. HALL, RUSSELL & CO., ABERDEEN, IN 1882, AND MESSRS. J. HOWDEN & CO., GLASGOW, IN 1887.

The collapsing coefficients are calculated on the external diameter of the furnaces over plain part.

Date of Test.	Length of Furnace.	No. of Rings.	Thickness of Plate in Inches.				External Diameter in Inches over Plain Part.	Greatest Difference in Diameter at any part.	Collapsing Pressure.	Collapsing Coefficient $\frac{P \times D}{T}$.	Ultimate Tensile Strength of Steel.	Collapsing Coefficients Reduced to Steel of 27 Tons Tensile.	Position of Collapse.
			Front End.	Middle.	Back End.	Mean.							
1882	6 ft. 5¾ ins. total; length of rings 18¼, 19, 19, and 20 ins.	4	—	—	—	1st ring, ½″ 2nd „ $\frac{15}{32}$″ F. 3rd „ $\frac{15}{32}$″ 4th „ ½″ B.	43	$\frac{9}{64}$	3rd ring collapsed at 700.	64,213	*	61,918	—
1887	7 ft. 0⅛ ins. total; length of each ring, 23 ins.	4	—	—	—	·546	43·09	No record.	1st ring, 840. 2nd „ 760. 3rd „ 840. 4th „ 835. Mean, 814.	64,240	*	61,945	—

* No record; probably 26 to 30 tons; assumed to be 28 tons.

TABLE II.—FOX'S PATENT CORRUGATED FURNACE.

Official Tests made at the Leeds Forge, Leeds, in 1882, 1890, and 1891.

The collapsing coefficients are calculated on the mean diameter of the furnaces.

Date of Test.	Length of Furnace.	No. of Corrugations.	Greatest Length of Flat at End.	Thickness of Plate in Inches.				Mean Diameter in Inches.	Greatest Difference in Diameter at any Part.	Collapsing Pressure.	Collapsing Coefficient $\frac{P \times D}{T}$.	Ultimate Tensile Strength of Steel	Collapsing Coefficients reduced to Steel of 27 Tons Tensile.	Position of Collapse
				Front End.	Middle.	Back End.	Mean.							
	Ft. Ins.													
Nov., 1882 ...	6 9	13	—	—	—	—	·52	35·875	—	900	62,091	22·7	73,852	—
Nov. 4, 1890 and Feb. 11, 1891 ...	6 $3\frac{15}{16}$	11	$5\frac{7}{8}$	·339	·364	·331	·349	34·125	$\frac{9}{32}$	830	81,157	29·05	75,430	On flat.
,, ,, ...	6 $3\frac{7}{8}$	11	6	·345	·384	·398	·378	34·25	$\frac{5}{32}$	800	72,486	29·17	67,094	On flat.*
,, ,, ...	6 7	12	6	·419	·463	·462	·452	33·625	$\frac{4}{32}$	1,130	84,062	29·26	77,569	2nd corrugation.
,, ,, ...	6 $8\frac{1}{16}$	12	$6\frac{9}{16}$	·471	·473	·454	·468	34·469	$\frac{4}{32}$	1,090	80,280	29·02	74,692	On flat.*
,, ,, ...	6 $5\frac{1}{2}$	11	$6\frac{5}{16}$	·577	·585	·551	·574	33·593	$\frac{7}{32}$	1,400	81,934	28·55	77,485	11th corrugation.
,, ,, ..	6 $6\frac{1}{16}$	11	$6\frac{1}{4}$	·542	·582	·596	·575	34·937	$\frac{8}{32}$	1,410	85,671	29·41	78,650	Front corrugation.*

* These three furnaces were annealed.

TABLE III.—FARNLEY SPIRALLY CORRUGATED FURNACES.

Official Tests made at the Works of the Farnley Iron Co., Limited, Farnley, near Leeds.

The collapsing coefficients are calculated on the mean diameter of the furnaces.

Date of Test.	Length of Furnace.	No. of Corrugations.	Greatest Length of Flat at End.	Thickness of Plate in Inches.				Mean Diameter in Inches.	Greatest Difference in Diameter at any part.	Collapsing Pressure.	Collapsing Coefficient $\frac{P \times D}{D}$.	Ultimate Tensile Strength of Steel.	Collapsing Coefficients Reduced to Steel of 27 Tons Tensile.	Position of Collapse.
				Front End.	Middle.	Back End.	Mean.							
	Ft. Ins.											Assumed.		
May, 1888 ...	6 5¼	—	—	—	—	—	·559	39·231	—	835	58,601	28	56,508	No record.
" ...	6 6¼	—	—	—	—	—	·548	39·132	—	850	60,697	28	58,529	—
" ...	6 6¼	—	—	—	—	—	·442	38·928	—	670	59,008	28	56,900	—
" ...	*6 6⅜	—	—	—	—	—	·446	39·394	—	570	50,346	28	48,548	—
" ...	6 6 5/16	—	—	—	—	—	·354	39·296	—	515	57,168	28	55,126	—

* This furnace was not so true as the others.

TABLE IV.—HOLMES'S CORRUGATED FURNACES.

Official Tests made at Messrs. Charles D. Holmes & Co., Hull, in 1891.

The collapsing coefficients are calculated on the diameters of the furnaces over flats.

Date of Test.	Length of Furnace.	No. of Corrugations.	Greatest Length of Flat at End.	Mean Thickness of Plate.		Diameter Outside of Plain Part.	Greatest Difference in Diameter at any Part.	Collapsing Pressure.	Collapsing Coefficient $\frac{P \times D}{T}$.	Ultimate Tensile Strength of Steel.	Collapsing Coefficients Reduced to Steel of 27 Tons Tensile.	Position of Collapse.
				Plain Part.	In Corrugation.							
	Ft. Ins.											
1891	7 0	4	No record.	·515	·458	35·37	$\frac{4}{32}$	950	65,245	27·3	64,528	One corrugation and two adjacent plain parts.
"	7 0	4	"	·452	·424	35·62	$\frac{10}{32}$	750	59,104	27·5	58,029	Plain part between two corrugations.
"	7 0	4	"	·557	—	35·5	$\frac{6}{32}$	920	58,635	26·8	59,072	Plain part and two adjacent corrugations.

TABLE V.—PURVES'S PATENT FURNACES.

OFFICIAL TESTS MADE AT THE WORKS OF MESSRS. JOHN BROWN & CO., SHEFFIELD, IN 1886 AND 1887.

The collapsing coefficients are calculated on the diameters of the furnaces over flats.

Date of Test.	Length of Furnace.	No. of Corrugations.	Greatest Length of Flat at End.	Thickness of Plate in Inches.				Diameter over Flats in Inches.	Greatest Difference in Diameter at any Part.	Collapsing Pressure.	Collapsing Coefficient $\frac{P \times D}{T}$.	Ultimate Tensile Strength of Steel.	Collapsing Coefficients Reduced to Steel of 27 Tons Tensile.	Position of Collapse.
				Front End.	Middle.	Back End.	Mean.							
	Ft. Ins.													
Mar. 12, 1886	6 6⅜	7	13 13/16	·561	·582	·548	·568	38·61	7/32	740	50,302	27·2	49,932	On flat.
" "	6 6⅜	7	13 13/16	·544	·554	·532	·546	38·685	11/32	760	53,847	26·6	54,656	"
1887	6 7⅛	8	7½	·299	·286	·310	·295	38·652	8/32	650	85,165	25·9	88,782	Between 1st and 2nd ribs.
"	6 7½	8	7½	·327	·302	·313	·311	38·591	6/32	635	78,795	27·9	76,253	Between 6th and 7th ribs.
"	6 7½	8	7½	·482	·535	·483	·509	38·83	15/32	800	61,029	26·1	63,133	From end to end.
"	6 7½	8	7½	·529	·589	·529	·559	38·868	8/32	800	55,625	27·9	53,831	" "
"	6 7½	8	7½	·583	·632	·597	·611	38·847	10/32	875	55,632	27·6	54,422	" "
"	6 7½	8	7½	·576	·638	·600	·613	38·788	11/32	873	55,239	28·3	52,701	" "

TABLE VI.—PURVES'S PATENT FURNACES.

OFFICIAL TESTS MADE AT MESSRS. JOHN BROWN & CO.'S WORKS, AT SHEFFIELD, IN 1889.

The collapsing coefficients are calculated on the diameters of furnaces over flats.

Date of Test.	Length of Furnace.	No. of Corrugations.	Greatest Length of Flat at End.	Thickness of Plate in Inches.				Diameter over Flats in Inches.	Greatest Difference in Diameter at any Part.	Collapsing Pressure.	Collapsing Coefficient $\frac{P \times D}{T}$.	Ultimate Tensile Strength of Steel.	Collapsing Coefficients Reduced to Steel of 27 Tons Tensile.	Position of Collapse.
				Front End.	Middle.	Back End.	Mean.							
1859	No record.	No rec.	9¼	No record.	No record.	No record.	·307	38·78	No record.	675	85,265	28·8	79,935	No record.
"	—	—	9⅜	—	—	—	·362	38·70	—	700	74,834	28·0	72,161	—
"	—	—	9⅜	—	—	—	·461	38·70	—	870	73,034	27·3	72,231	—
"	—	—	9⅜	—	—	—	·466	38·72	—	950	78,935	29·3	72,738	—
"	—	—	9½	—	—	—	·585	38·63	—	1,065	70,326	28·7	66,160	—
"	—	—	9 11/16	—	—	—	·578	38·65	—	1,145	76,564	27·4	75,446	—
Dec. 23, 1890	—	—	—	—	—	—	·522	38·75	—	1,020	75,718	—	—	—

Corrugations spaced 9 inches apart. No record of length of furnaces.

TABLE VII.—MORISON'S SUSPENSION FURNACE.

Official Tests made at the Leeds Forge, Leeds, in 1891.

The collapsing coefficients are calculated on the *mean* diameter of the furnaces.

Date of Test.	Length of Furnace.	No. of Corrugations.	Greatest Length of Flat at End.	Thickness of Plate in Inches.				Mean Diameter in Inches.	Greatest Difference in Diameter at any Part.	Collapsing Pressure.	Collapsing Coefficient $\frac{P \times D}{T}$.	Ultimate Tensile Strength of Steel.	Collapsing Coefficients Reduced to Steel of 27 Tons Tensile.	Position of Collapse.
				Front End.	Middle.	Back End.	Mean.							
	Ft. Ins.													
Sept. 25 & 26, 1891	6 5½	9	4¾	·340	·310	·340	·325	34·156	11/32	795	83,550	27·64	81,615	Flat at front end.
" "	6 7½	9	4½	·341	·391	·368	·373	34·265	3/32	900	82,677	27·34	81,648	2nd corrugation from front.
" "	6 5½	9	4½	·445	·492	·451	·470	34·444	19/64	1,100	80,613	26·92	80,852	Uniformly on weld.
" "	6 6¾	9	4¾	·452	·458	·441	·452	34·687	11/32	1,050	80,578	26·56	81,913	7th, 8th, and 9th corrugation at weld.
" "	6 7½	9	4¾	·535	·516	·554	·530	34·719	3/32	1,300	85,159	27·52	83,550	1st, 2nd, and 3rd corrugation.
" "	6 7	9	5	·556	·573	·565	·567	34·078	7/32	1,340	80,537	27·09	80,269	Flat at front and 1st corrution.

Note.—All these furnaces were annealed in the presence of the Board of Trade officer.

1891	Holmes ...	Lloyd's ...	least external or diam. over flats	35·37	·515	65,245	64,528	950	945	166·7	5·70		
	" ...	" ...		35·5	·557	58,635	59,072	920	945	184·0	5·00		
										mean	5·35	27·05	5·34
May, 1888 ...	Farnley ...	Lloyd's ...	over corrgtns.	41·54	·559	58,601	56,508	835	912	152·5	5·48		
	" ...	" ...	" "	41·43	·548	60,697	58,529	850	912	149·0	5·70		
										mean	5·59	Assmd. 28	5·39
Sept. 25 and 26. 1891, with 1892 coefficients	Morison	Board of Trade	least external	33·779	·530	85.159	83,550	1,300	13,500	211·7	6·14		
	"	"	" "	33·212	·567	80,537	80,269	1,340	13,500	230·5	5·81		
										mean	5·98	27·305	5·91
	"	Lloyd's ...	over corrgtns.	36·719	·530	85,159	83,550	1,300	1,259	222·2	5·85		
	"	" ...	" "	36·078	·567	80,537	80,269	1,340	1,259	246·8	5·43		
										mean	5·64	27·305	5·58

APPENDIX.

MARINE BOILER FURNACES.

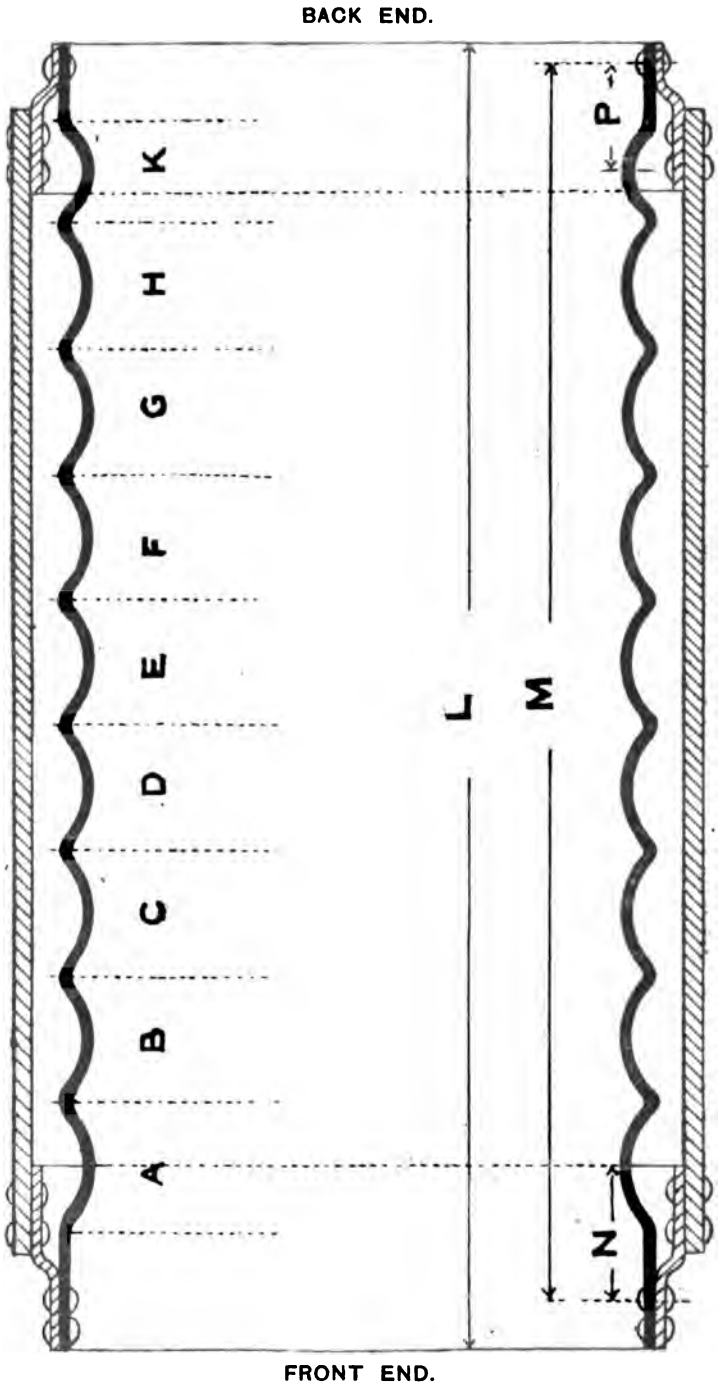


FIG. 1.

APPENDIX.

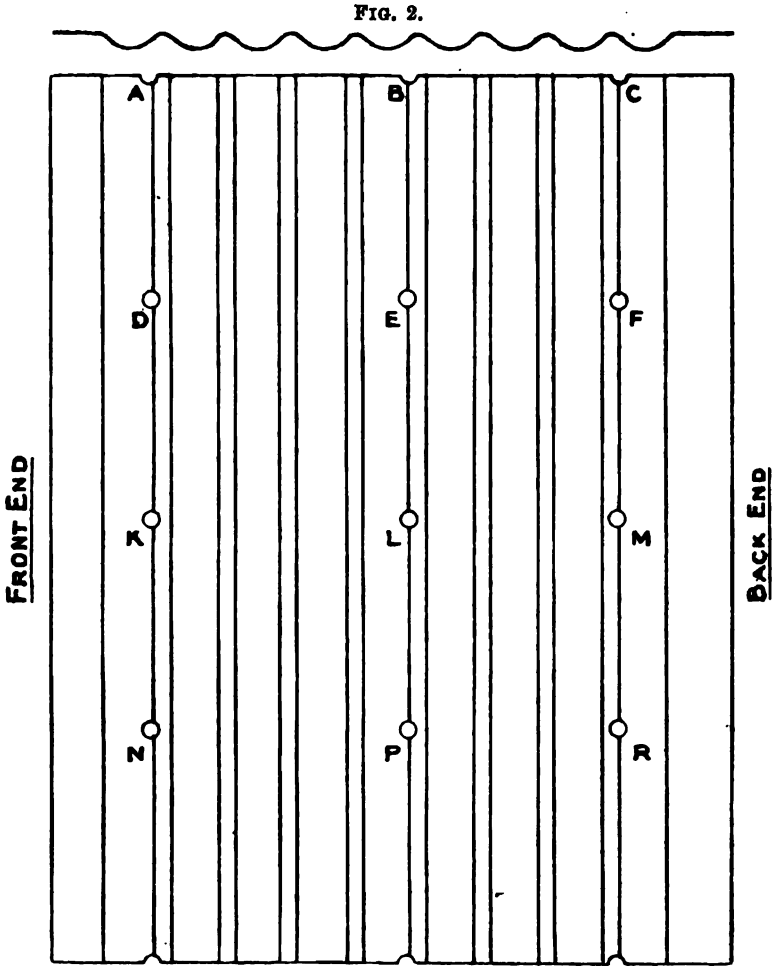
TESTS OF SIX MORISON'S SUSPENSION FURNACES MADE AT THE LEEDS FORGE, SEPTEMBER 25TH AND 26TH, 1891.

DIAMETER OF FLUES.—FIG. 1.

Where Taken.	No. 2,834.		No. 4,897.		No. 4,358.		No. 4,359.		No. 2,833.		No. 4,296.	
	Vertically.	Horizontally.	Vertically.	Horizontally.	Vertically.	Horizontally.	Vertically.	Horizontally.	Vertically.	Horizontally.	Vertically.	Horizontally.
	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
A ...	2 $8\frac{1}{32}$	2 $7\frac{23}{32}$	2 $8\frac{5}{64}$	2 $8\frac{1}{32}$	2 $8\frac{3}{4}$	2 $8\frac{25}{32}$	2 $8\frac{5}{16}$	2 $8\frac{7}{32}$	2 $8\frac{29}{32}b$	2 $8\frac{33}{32}$F	2 $8\frac{3}{32}b$	2 $8\frac{1}{32}$
B ...	2 $8\frac{1}{8}$	2 $8\frac{1}{32}$	2 $8\frac{7}{16}$	2 $8\frac{3}{8}$	2 $8\frac{3}{4}$	2 $8\frac{3}{4}$	2 $8\frac{5}{16}$	2 $8\frac{1}{4}$	2 $8\frac{7}{8}$	2 $8\frac{13}{16}$	2 $8\frac{1}{8}$	2 $8\frac{1}{8}$
C ...	2 $8\frac{1}{16}$	2 8	2 $8\frac{7}{16}$	2 $8\frac{7}{16}$	2 $8\frac{11}{16}$	2 $8\frac{11}{16}$	2 $8\frac{11}{32}$	2 $8\frac{9}{32}$	2 $8\frac{13}{16}$	2 $8\frac{13}{16}$	2 $8\frac{1}{32}$	2 $8\frac{9}{32}$
D ...	2 $8\frac{1}{16}$	2 8	2 $8\frac{3}{8}f$	2 $8\frac{3}{8}f$	2 $8\frac{3}{4}$	2 $8\frac{3}{4}$	2 $8\frac{13}{32}$	2 $8\frac{13}{32}$	2 $8\frac{3}{4}$	2 $8\frac{13}{16}$	2 $8\frac{1}{8}$	2 $8\frac{7}{32}$
E ...	2 $8\frac{9}{32}$	2 $8\frac{3}{16}$	2 $8\frac{1}{2}$	2 $8\frac{31}{64}$	2 $8\frac{3}{4}$	2 $8\frac{33}{4}b$	2 $8\frac{9}{16}$	2 $8\frac{19}{32}$	2 $8\frac{11}{16}$	2 $8\frac{3}{4}$	2 $8\frac{1}{64}$	2 $8\frac{3}{16}$
F ...	2 $8\frac{9}{32}$	2 $8\frac{9}{32}$	2 $8\frac{15}{32}$	2 $8\frac{15}{32}$	2 $8\frac{3}{4}$	2 $8\frac{23}{32}$	2 $8\frac{1}{8}$	2 $8\frac{19}{32}$	2 $8\frac{19}{32}$	2 $8\frac{5}{8}$	2 $7\frac{29}{32}$	2 $8\frac{1}{32}$
G ...	2 $8\frac{9}{32}$	2 $8\frac{9}{32}$	2 $8\frac{3}{16}$	2 $8\frac{5}{32}$	2 $8\frac{21}{32}$	2 $8\frac{19}{32}$	2 $8\frac{3}{8}$	2 $8\frac{17}{32}$	2 $8\frac{5}{8}$	2 $8\frac{5}{8}$	2 $8\frac{1}{32}$	2 $8\frac{9}{32}$
H ...	2 $8\frac{1}{8}$	2 $8\frac{5}{32}$	2 $8\frac{1}{8}$	2 $8\frac{1}{8}$	2 $8\frac{21}{32}$	2 $8\frac{21}{32}$	2 $8\frac{3}{8}$	2 $8\frac{19}{32}$	2 $8\frac{9}{16}$	2 $8\frac{21}{32}b$	2 $8\frac{3}{16}$	2 $7\frac{31}{32}$
K ...	2 $8\frac{3}{8}$	2 $8\frac{13}{32}$	2 $7\frac{7}{8}$	2 $7\frac{13}{16}$	2 $8\frac{21}{32}f$	2 $8\frac{23}{32}f$	2 $8\frac{7}{16}$	2 $8\frac{47}{64}$	2 $8\frac{9}{16}$	2 $8\frac{21}{32}$	2 $8\frac{3}{16}$	2 $7\frac{31}{32}$
	Ft. In.		Ft. In.		Ft. In.		Ft. In.		Ft. In.		Ft. In.	
L ...	6 $9\frac{3}{4}$		7 1		6 11		7 0		7 $0\frac{1}{2}$		7 0	
M ...	6 $5\frac{1}{2}$		6 $7\frac{1}{8}$		6 $6\frac{3}{4}$		6 $5\frac{1}{2}$		6 $7\frac{1}{2}$		6 7	
N ...	$8\frac{3}{4}$		$8\frac{1}{2}$		$8\frac{3}{4}$		$8\frac{1}{2}$		$8\frac{3}{4}$		9	
P ...	$5\frac{1}{16}$		$6\frac{5}{8}$		6		5		7		6	

All dimensions taken by Board of Trade officers, and the materials tested by Messrs. Kirkaldy, of London.

FIG. 2.



MEASUREMENTS FOR THICKNESS.—FIG. 2.

Position of Hole.	No. 2,834.	No. 4,597.	No. 4,358.	No. 4,359.	No. 2,833.	No. 4,296.
A ...	·313	·346	·424	·529	·537	·593
B ...	·295	·409	·440	·487	·532	·589
C ..	·339	·367	·435	·443	·564	·606
D ...	·339	·342	·444	·441	·542	·557
E ...	·315	·393	·456	·484	·514	·577
F ...	·353	·365	·439	·453	·557	·558
K ...	·345	·341	·466	·452	·529	·553
L ...	·307	·384	·464	·501	·512	·572
M ...	·325	·367	·448	·457	·550	·575
N ...	·337	·341	·445	·442	·536	·559
P ...	·309	·397	·455	·492	·522	·571
R ...	·343	·371	·436	·445	·557	·563

NOMINAL THICKNESS, $\frac{5}{16}$ INCH.—No. 2,834.

	Measurements taken at A.		Measurements taken at E.		Measurements taken at H.		Length.	
	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.	Right.	Left.
Measurements taken before test	Inches. $32\frac{1}{32}$	Inches. $31\frac{23}{32}$	Inches. $32\frac{9}{32}$	Inches. $32\frac{6}{32}$	Inches. $32\frac{4}{32}$	Inches. $32\frac{5}{32}$	...	...
Pressure in lbs. per square inch.	Movement.		Movement.		Movement.		Extension on $72\frac{11}{16}$ inches.	
100	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
200	"	"	"	"	"	"	"	"
300	$\frac{1}{64}$ in.	"	"	$\frac{1}{32}$ in.	$\frac{1}{32}$ in.	"	"	"
400	$\frac{1}{64}$ F. in.	"	"	"	"	"	"	"
500	"	"	"	"	"	"	"	"
600	$\frac{1}{32}$ in.	"	line out	$\frac{1}{32}$ F. in.	$\frac{1}{16}$ in.	"	"	"
0	Pressure released to zero. No permanent set.							
700	$\frac{1}{16}$ in.	Nil.	line out	$\frac{1}{32}$ F. in.	$\frac{1}{16}$ in.	"	"	"
795	Collapsed gradually on flat at front end left-hand side, also on weld at bottom front end.							
0	$31\frac{7}{16}$ in.	$30\frac{11}{16}$ in.	$32\frac{19}{32}$ in.	$32\frac{8}{32}$ in.	$32\frac{8}{32}$ in.	$32\frac{5}{32}$ in.	"	"

NOMINAL THICKNESS, $\frac{5}{16}$ INCH = ·3125.—No. 2,834.

Measurements for Thickness.

No. of Test Hole.	Front.	Middle.	Back.
1 weld.	·313	·295	·339
2	·339	·315	·353
3	·345	·307	·325
4	·337	·309	·343
Mean of unwelded plate	·340	·310	·340

Mean thickness of front end of plate		·340
" " middle " "		·310
" " back " "		·340
" " the plate		·325
" " the welded portion of the plate ... ... being ·015 less than the mean thickness of the unwelded plate.		·315
" " the unwelded plate was ... ... or ·0125 greater than the nominal thickness,		·325

Mechanical Tests of Material.—No. 2,834.

Tensile Tests of Six Specimens cut from the Plate from which the above-numbered Flue Tube was made.

Test No.	Marks on Piece	Dimensions. Broad.	Dimensions. Thick.	Dimensions. Area.	Limit of Elasticity. Lbs. per sq. in.	Limit of Elasticity. Tons per sq. in.	Breaking Load. Lbs. per sq. in.	Breaking Load. Tons per sq. in.	Ratio of Limit to Break.	Extension on 10 in. Per cent.	Reduction of Area. Per cent.	Extension on 10 in. at 40,000 lbs. per sq. in.	Extension on 10 in. at 50,000 lbs. per sq. in.
Not Annealed.													
18,885	2,834 P.S.	1·496	·338	·506	41,870	18·69	62,200	27·77	·673	23·6	50·5	·04	·46*
18,886	"	1·496	·342	·512	42,420	18·94	61,980	27·67	·685	25·6	53·2	·02	·47*
18,887	"	1·496	·338	·506	43,590	19·46	61,540	27·48	·708	23·7	50·9	·04	·47*
		Mean ...			42,627	19·03	61,907	27·64	·689	24·3	51·5	·02	·47
Annealed.													
18,888	"	1·493	·340	·508	35,480	15·84	59,430	26·53	·597	25·6	47·5	·29	·55*
18,889	"	1·493	·325	·485	38,220	17·06	59,950	26·77	·637	23·6	50·8	·27	·54†
18,890	"	1·496	·335	·501	36,880	16·47	59,130	26·40	·624	25·3	46·5	·26	·65‡
		Mean ...			36,860	16·46	59,503	26·57	·619	24·8	48·3	·27	·58

* Silky. † Silky, slight lamination. ‡ Silky, very slight lamination.

Compressive Tests of Six Specimens cut from the Plate from which the above-numbered Flue Tube was made.

Test No.	Marks on Piece.	Dimensions. Broad.	Dimensions. Thick.	Dimensions. Area.	Buckling Load. Lbs. per sq. in.	Buckling Load. Tons per sq. in.	Compression on 10 in. Length. 20,000 lbs. per sq. in.	Compression on 10 in. Length. 30,000 lbs per sq. in.	Compression on 10 in. Length. Buckling Load per sq. in.
Not Annealed.									
18,891	2,834 P.S.	1·490	·334	·497	30,020	13·40	·02	·06	·06*
18,892	..	1·493	·340	·508	32,570	14·54	·02	·03	·06*
18,893	..	1·492	·345	·515	36,420	16·26	·02	·03	·05*
		Mean			33,003	14·73	·02	·04	·057
Annealed.									
18,894	"	1·500	·330	·495	25,800	11·52	·02	...	·06
18,895	"	1·494	·336	·502	29,990	13·39	·01	...	·05
18,896	"	1·496	·340	·509	29,330	13·09	·01	...	·06
		Mean			28,373	12·67	·013	...	·057

* The pieces gave way by buckling without cracking in all cases.

NOMINAL THICKNESS, $\frac{5}{16}$ INCH.—NO. 4,897.

	Measurements taken at A.		Measurements taken at E.		Measurements taken at K.		Length.	
	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.	Right.	Left.
Measurements taken before test... ...	Ft. In. 2 $8\frac{5}{64}$	Ft. In. 2 $8\frac{1}{32}$	Ft. In. 2 $8\frac{1}{8}$	Ft. In. 2 $8\frac{11}{64}$	Ft. In. 2 $7\frac{14}{16}$	Ft. In. 2 $7\frac{13}{16}$	...	...
Pressure in lbs. per square inch.	Movement.		Movement.		Movement.		Extension on 6 ft. 2 in.	
100	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
200	"	"	"	"	"	"	"	"
300	$\frac{1}{64}$ in.	$\frac{1}{64}$ in.	$\frac{1}{64}$ in.	$\frac{1}{64}$ in.	$\frac{1}{64}$ in.	"	"	"
400	"	"	"	"	"	"	"	"
500	"	"	"	"	"	"	"	"
600	$\frac{1}{32}$ in.	$\frac{1}{32}$ in.	"	$\frac{1}{32}$ in.	$\frac{1}{64}$ in.	$\frac{1}{64}$ in.	"	"
700	"	"	"	"	"	"	"	"
0	Pressure released to zero. No permanent set.							
800	$\frac{1}{32}$ in.	$\frac{1}{32}$ in.	$\frac{1}{64}$ in.	$\frac{1}{32}$ in.	$\frac{1}{16}$ in.	$\frac{1}{64}$ in.	"	"
900	Collapsed on second corrugation from front end, 18 inches from weld.							
0	Ft. In. 2 $7\frac{9}{16}$	Ft. In. 2 $8\frac{1}{32}$	Ft. In. 2 $8\frac{3}{16}$	Ft. In. 2 $8\frac{11}{16}$	Ft. In. 2 $7\frac{14}{16}$	Ft. In. 2 $7\frac{4}{4}$	"	"

NOMINAL THICKNESS, $\frac{5}{16}$ INCH = ·3125.—NO. 4,897.

Measurements for Thickness.

No. of Test Hole.	Front.	Middle.	Back.
1 weld.	·346	·409	·367
2	·342	·393	·365
3	·341	·384	·367
4	·341	·397	·371
Mean of unwelded plate	·341	·391	·368

Mean thickness of front end of plate		·341
" " middle		·391
" " back "		·368
" " the plate		·373
" " the welded portion of the plate ... ... being ·008 greater than the mean thickness of the unwelded plate.		·374
" " the unwelded plate was ... ... or ·0605 greater than the nominal thickness.		·373

MECHANICAL TESTS OF MATERIAL.—No. 4,897, $\frac{5}{16}$ INCH THICK.

TENSILE TESTS of Six Specimens cut from the Plate from which the above-numbered Flue Tube was made.

Test No.	Marks on Piece.	Dimensions.			Limit of Elasticity.		Breaking Load.		Ratio of Limit to Break.	Extension on 10 in. Per cent.	Reduction of Area. Per cent.	Extension on 10 in. at	
		Broad.	Thick.	Area.	Lbs. per sq. in.	Tons per sq. in.	Lbs. per sq. in.	Tons per sq. in.				40,000 lbs. per sq. in.	50,000 lbs. per sq. in.
NOT ANNEALED.													
19,205	4,897 P.S. C. 882	1·496	·340	·509	40,030	17·87	60,660	27·08	·660	24·1	53·3	·12	·44*
19,206	"	1·495	·342	·511	42,720	19·07	61,520	27·46	·695	26·7	56·4	·03	·49*
19,207	"	1·497	·343	·513	41,890	18·70	61,530	27·47	·681	23·8	54·0	·04	·43*
		Mean ...			41,547	18·55	61,237	27·34	·679	24·9	54·6	·06	·45
ANNEALED.													
19,208	"	1·495	·350	·523	39,310	17·54	58,840	26·27	·668	25·5	57·8	·16	·61*
19,209	"	1·496	·350	·524	41,960	18·73	58,660	26·19	·715	26·3	56·2	·13	·62*
19,210	"	1·498	·350	524	41,530	18·54	59,220	26·44	·701	24·3	53·8	·04	·57*
		Mean ...			40,933	18·27	58,907	26·30	·695	25·4	55·9	·11	·60

* Silky.

COMPRESSIVE TESTS of Six Specimens cut from the Plate from which the above-numbered Flue Tube was made.

Test No.	Marks on Piece.	Dimensions.			Buckling Load.		Compression on 10 in. Length.		
		Broad.	Thick.	Area.	Lbs. per sq. in.	Tons per sq. in.	20,000 lbs. per sq. in.	30,000 lbs. per sq. in.	Buckling Load per sq. in.
NOT ANNEALED.									
19,211	4,897 P.S. C. 882	1·508	·350	·528	33,870	15·12	·01	·03	·06
19,212	"	1·508	·350	·528	36,550	16·32	·01	·025	·07*
19,213	"	1·511	·346	·528	40,620	18·13	·02	·03	·08
		Mean			37,013	16·52	·013	·028	·07
ANNEALED.									
19,214	"	1·512	·348	·526	38,960	17·39	·02	·03	·06*
19,215	"	1·512	·346	·523	41,500	18·53	·02	·03	·08
19,216	"	1·512	·346	·523	35,840	16·00	·02	·03	·07
		Mean			38,767	17·31	·02	·03	·07

* Buckled without cracking.

NOMINAL THICKNESS, $\frac{7}{16}$ INCH.—No. 4,358.

	Measurements taken at A.		Measurements taken at E.		Measurements taken at K.		Length.	
	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.	Right.	Left.
Measurements taken before test... ...	Ft. In. 2 $8\frac{3}{4}$	Ft. In. 2 $8\frac{25}{32}$	Ft. In. 2 $8\frac{3}{4}$	Ft. In. 2 $8\frac{3}{4}b$	Ft. In. 2 $8\frac{31}{32}f$	Ft. In. 2 $8\frac{25}{32}f$	...	...
Pressure in lbs. per square inch.	Movement.		Movement.		Movement.		Extension on 6 ft. 2 in.	
100	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
200	"	"	"	"	"	"	"	"
300	$\frac{1}{64}$ in.	"	"	"	"	"	"	"
400	"	"	line in	line in	$\frac{1}{64}$ in.	"	"	"
500	"	"	$\frac{1}{64}$ in.	"	"	"	"	"
600	$\frac{1}{32}$ in.	"	"	$\frac{1}{32}$ in.	$\frac{1}{32}$ in.	"	"	"
700	"	line in	"	"	"	"	"	"
0	Pressure released to zero.			No permanent set.				
800	$\frac{1}{32}$ in.	line in	$\frac{1}{64}$ in.	$\frac{1}{32}$ in.	$\frac{1}{32}$ in.	"	"	"
900	$\frac{1}{16}$ in.	"	$\frac{1}{32}$ in.	"	$\frac{1}{16}$ in.	"	trace	trace
1,000 (scale began to come off)	$\frac{5}{64}$ in.	"	"	"	$\frac{3}{32}$ in.	$\frac{7}{64}$ in.	"	"
1,050	"	$\frac{1}{64}$ in.	"	"	$\frac{11}{32}$ in.	$\frac{1}{8}$ in.	$\frac{1}{32}$ in. out	"
	Collapsed on weld at seventh, eighth, and ninth corrugations.							
0	Ft. In. 2 $8\frac{23}{32}$	Ft. In. 2 $8\frac{24}{32}$	Ft. In. 2 $8\frac{23}{32}$	Ft. In. 2 $8\frac{23}{32}$	Ft. In. 2 $8\frac{11}{32}$	Ft. In. 2 $8\frac{9}{16}$		

NOMINAL THICKNESS, $\frac{7}{16}$ INCH = ·4375.—No. 4,358.

Measurements for Thickness.

No. of Test Hole.	Front.	Middle.	Back.
1 weld	·424	·440	·435
2	·444	·456	·439
3	·466	·464	·448
4	·445	·455	·436
Mean of unwelded plate	·452	·458	·441

Mean thickness of front end of plate	·452
" " middle	·458
" " back " "	·441
" " the plate	·452
" " the welded portion of the plate ... ... being ·028 less than the mean thickness of the unwelded plate.	·433
" " the unwelded plate ... ... or ·0145 greater than the nominal thickness.	·452

MECHANICAL TESTS OF MATERIAL.—No. 4,358, $\frac{7}{16}$ INCH THICK.

TENSILE TESTS of Six Specimens cut from the Plate from which the above-numbered Flue Tube was made.

Test No.	Marks on Piece.	Dimensions. Broad.	Dimensions. Thick.	Dimensions. Area.	Limit of Elasticity. Lbs. per sq. in.	Limit of Elasticity. Tons per sq. in.	Breaking Load. Lbs. per sq. in.	Breaking Load. Tons per sq. in.	Ratio of Limit to Break.	Extension on 10 in. Per cent.	Reduction of Area. Per cent.	Extension on 10 in. at 40,000 lbs. per sq. in.	Extension on 10 in. at 50,000 lbs. per sq. in.
NOT ANNEALED.													
18,953	4,358 P.S. A. 707	1·496	·455	·681	42,640	19·03	59,510	26·57	·716	22·1	48·6	·02	·35*
18,954	"	1·496	·452	·676	44,730	19·97	59,230	26·44	·755	25·3	48·8	·02	·37*
18,955	"	1·495	·456	·682	43,170	19·28	59,730	26·67	·723	23·3	44·6	·02	·36*
		Mean ...			43,513	19·43	59,490	26·56	·731	23·6	47·3	·023	·36
ANNEALED.													
18,956	"	1·496	·454	·679	41,950	18·73	54,810	24·47	·765	21·0	52·1	·05	·75†
18,957	"	1·496	·458	·685	37,460	16·73	54,620	24·39	·686	23·3	52·6	·32	·80†
18,958	"	1·496	·453	·678	35,890	16·02	55,330	24·70	·649	27·8	54·9	·35	·77*
		Mean ...			38,433	17·16	54,920	24·52	·700	24·0	53·2	·24	·77

* Silky, very slight lamination. † Silky.

COMPRESSIVE TESTS of Six Specimens cut from the Plate from which the above-numbered Flue Tube was made.

Test No.	Marks on Piece.	Dimensions. Broad.	Dimensions. Thick.	Dimensions. Area.	Buckling Load. Lbs. per sq. in.	Buckling Load. Tons per sq. in.	Compression on 10 in. Length. 20,000 lbs. per sq. in.	Compression on 10 in. Length. 30,000 lbs. per sq. in.	Compression on 10 in. Length. Buckling Load per sq. in.
NOT ANNEALED.									
18,959	4,358 P.S. A. 707	1·498	·460	·689	37,550	16·76	·02	·03	·06
18,960	"	1·500	·460	·690	40,020	17·87	·02	·03	·08*
18,961	"	1·498	·460	·689	40,080	17·89	·02	·03	·07
		Mean			39,217	17·51	·02	·03	·07
ANNEALED.									
18,962	"	1·503	·453	·681	36,120	16·18	·03	·04	·08
18,963	"	1·500	·453	·680	35,210	15·72	·02	·03	·06*
18,964	"	1·503	·453	·681	34,350	15·34	·02	·03	·06
		Mean			35,227	15·73	·023	·033	·07

* Buckled without cracking.

NOMINAL THICKNESS, $\frac{7}{16}$ INCH.—No. 4,359.

	Measurements taken at A.		Measurements taken at E.		Measurements taken at K.		Length.	
	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.	Right.	Left.
Measurements taken before test... ...	Ft. In. 2 $8\frac{5}{16}$	Ft. In. 2 $8\frac{7}{32}$	Ft. In. 2 $8\frac{9}{16}$	Ft. In. 2 $8\frac{19}{32}$	Ft. In. 2 $8\frac{7}{16}$	Ft. In. 2 $8\frac{47}{64}$	...	...
Pressure in lbs. per square inch.	Movement.		Movement.		Movement.		Extension on 6 ft. 2 in.	
100	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
200	"	"	"	"	"	"	"	"
300	"	"	"	"	$\frac{1}{32}$ in.	"	"	"
400	$\frac{1}{32}$ in.	"	$\frac{1}{64}$ in.	"	"	"	"	"
500	"	"	"	"	"	trace	"	"
600	"	"	"	"	$\frac{3}{64}$ in.	$\frac{1}{64}$ out	"	"
700	$\frac{3}{64}$ in.	"	$\frac{1}{32}$ in.	"	"	"	"	"
800	"	"	"	"	"	"	"	"
900	$\frac{5}{64}$ in.	"	"	"	$\frac{5}{64}$ in.	"	line out	"
0	Pressure released to zero. No permanent set.							
1,000	$\frac{5}{64}$ in.	Nil.	$\frac{5}{64}$ in.	Nil.	$\frac{5}{64}$ in.	$\frac{1}{64}$ out	"	"
1,100	Collapsed uniformly on weld.							
0	Ft. In. 2 $8\frac{1}{16}$	Ft. In. 2 $8\frac{17}{64}$	Ft. In. 2 $7\frac{3}{4}$	Ft. In. 2 $8\frac{19}{32}$	Ft. In. 2 $8\frac{5}{16}$	Ft. In. 2 $8\frac{49}{64}$	Inch. $\frac{3}{64}$	"

NOMINAL THICKNESS, $\frac{7}{16}$ INCH = ·4375.—No. 4,359.

Measurements for Thickness.

No. of Test Hole.	Front.	Middle.	Back.
1 weld	·529	·487	·443
2	·441	·484	·453
3	·452	·501	·457
4	·442	·492	·445
Mean of unwelded plate	·445	·492	·451

Mean thickness of front end of plate	·445
" " middle " "	·492
" " back " "	·451
" " the plate	·470
" " the welded portion of the plate ... ... being ·024 greater than the mean thickness of the unwelded plate.	·486
" " the unwelded plate was ... ... or ·0325 greater than the nominal thickness.	·470

MECHANICAL TESTS OF MATERIAL.—No. 4,359, $\frac{7}{16}$ INCH THICK.

TENSILE TESTS of Six Specimens cut from the Plate from which the above-numbered Flue Tube was made.

Test No.	Marks on Piece.	Dimensions. Broad.	Dimensions. Thick.	Dimensions. Area.	Limit of Elasticity. Lbs. per sq. in.	Limit of Elasticity. Tons per sq. in.	Breaking Load. Lbs. per sq. in.	Breaking Load. Tons per sq. in.	Ratio of Limit to Break.	Extension on 10 in. Per cent.	Reduction of Area. Per cent.	Extension on 10 in. at 40,000 lbs. per sq. in.	Extension on 10 in. at 50,000 lbs. per sq. in.
NOT ANNEALED.													
18,968	4,359 P.S. A. 707	1·497	·420	·629	46,820	20·90	60,600	27·06	·772	22·0	47·4	·03	·31*
18,969	"	1·497	·425	·636	44,040	19·66	60,200	26·88	·731	22·7	51·1	·03	·32*
18,970	"	1·496	·418	·625	45,560	20·34	60,070	26·82	·758	21·8	48·2	·03	·36†
		Mean ...			45,473	20·30	60,290	26·92	·754	22·2	48·9	·03	·33
ANNEALED.													
18,971	"	1·497	·425	·636	39,820	17·78	59,090	25·04	·710	23·6	53·6	·21	·66*
18,972	"	1·496	·420	·628	38,500	17·19	55,930	24·97	·688	19·9	48·7	·18	·69‡
18,973	"	1·497	·428	·641	37,960	16·95	55,390	24·73	·685	24·5	51·5	·36	·81*
		Mean ...			38,760	17·31	55,503	24·91	·694	22·7	51·3	·25	·72

* Silky. † Silky, very slight lamination. ‡ Silky, slight lamination.

COMPRESSIVE TESTS of Six Specimens cut from the Plate from which the above-numbered Flue Tube was made.

Test No.	Marks on Piece.	Dimensions. Broad.	Dimensions. Thick.	Dimensions. Area.	Buckling Load. Lbs. per sq. in.	Buckling Load. Tons per sq. in.	Compression on 10 in. Length. 20,000 lbs. per sq. in.	Compression on 10 in. Length. 30,000 lbs. per sq. in.	Compression on 10 in. Length. Buckling Load per sq. in.
NOT ANNEALED.									
18,974	4,359 P.S. A. 707	1·500	·418	·627	44,480	19·86	·01	·02	·07
18,975	"	1·500	·424	·636	42,470	18·96	·02	·03	·09*
18,976	"	1·500	·425	·638	38,680	17·27	·02	·03	·07
		Mean			41,877	18·70	·017	·027	·08
ANNEALED.									
18,977	"	1·500	·422	·633	36,830	16·45	·02	·03	·08
18,978	"	1·500	·425	·638	35,310	15·76	·02	·03	·07*
18,979	"	1·500	·428	·642	34,220	15·28	·01	·03	·06
		Mean			35,453	15·83	·017	·03	·07

* Buckled without cracking.

NOMINAL THICKNESS, $\frac{9}{16}$ INCH.—NO. 2,833.

	Measurements taken at A.		Measurements taken at E.		Measurements taken at H.		Length.	
	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.	Right.	Left.
Measurements taken before test	Inches. $32\frac{24}{32}b$	Inches. $32\frac{23}{32}f$	Inches. $32\frac{23}{32}$	Inches. $32\frac{24}{32}$	Inches. $32\frac{18}{32}$	Inches. $32\frac{11}{32}b$	...	...
Pressure in lbs. per square inch.	Movement.		Movement.		Movement.		Extension on 74 inches.	
100	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
200	$\frac{1}{32}b$ in.	"	"	"	"	"	$\frac{1}{64}$ in.	$\frac{1}{64}$ in.
300	"	"	"	"	"	"	$\frac{1}{32}$ in.	$\frac{1}{32}$ in.
400	"	"	"	"	"	"	"	"
500	"	"	"	"	$\frac{1}{32}$ in.	$\frac{1}{32}$ in.	"	"
600	"	"	"	"	"	"	"	"
700	$\frac{1}{32}f$ in.	"	"	"	"	"	back to original.	
800	"	"	"	b in.	"	"		
900	"	"	"	"	$\frac{1}{16}$ in.	"	"	"
1,000	"	$\frac{1}{32}b$ in.	$\frac{1}{32}$ in.	$\frac{1}{32}b$ in.	"	"	"	"
1,100	$\frac{3}{32}$ in.	$\frac{1}{32}$ in.	"	"	"	"	"	"
	Pressure released to zero.							
0	$\frac{1}{16}b$ in.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
1,200	$\frac{1}{4}$ in.	$\frac{3}{32}f$ in.	$\frac{1}{16}f$ in.	"	"	$\frac{1}{32}b$ in.	"	"
1,300	Collapsed gradually first, second, and third corrugations, front end, top left-hand side.							
0	$31\frac{30}{32}$ in.	$32\frac{17}{32}$ in.	$32\frac{3}{32}$ in.	$33\frac{4}{32}$ in.	$32\frac{14}{32}$ in.	$32\frac{23}{32}$ in.	"	"

NOMINAL THICKNESS, $\frac{9}{16}$ INCH = ·5625.—NO. 2,833.

Measurements for Thickness.

No. of Test Hole.	Front.	Middle.	Back.
1 weld	·537	·532	·564
2	·542	·514	·557
3	·529	·512	·550
4	·536	·522	·557
Mean of unwelded plate	·535	·516	·554

Mean thickness of front end of plate	·535
" " middle " "	·516
" " back " "	·554
" " the plate	·530
" " the welded portion of the plate ... ... being ·0093 greater than the mean thickness of the unwelded plate.	·5443
" " the unwelded plate was ... ... or ·0325 less than the nominal thickness.	·530

MECHANICAL TESTS OF MATERIAL.—No. 2,833.

TENSILE TESTS of Six Specimens cut from the Plate from which the above-numbered Flue Tube was made.

Test No.	Marks on Piece.	Dimensions. Broad.	Thick.	Area.	Limit of Elasticity. Lbs. per sq. in.	Tons per sq. in.	Breaking Load. Lbs. per sq. in.	Tons per sq. in.	Ratio of Limit to Break.	Extension on 10 in. Per cent.	Reduction of Area. Per cent.	Extension on 10 in. at 40,000 lbs. per sq. in.	50,000 lbs. per sq. in.
NOT ANNEALED.													
18,870	2,833 P.S.	1·494	·530	·792	35,980	16·06	60,680	27·09	·593	23·5	52·3	·24	·46*
18,871	"	1·494	·535	·799	44,140	19·71	63,400	28·30	·697	22·1	51·9	·19	·35*
18,872	"	1·494	·535	·799	36,150	16·14	60,870	27·18	·594	24·4	44·1	·23	·39†
		Mean ...			38,757	17·30	61,650	27·52	·628	23·3	49·4	·22	·40
ANNEALED.													
18,873	"	1·492	·538	·803	37,670	16·82	61,630	27·51	·611	23·8	50·5	·12	·45*
18,874	"	1·490	·534	·796	41,810	18·67	60,550	27·04	·690	25·5	51·9	·05	·50‡
18,875	"	1·490	·535	·797	41,980	18·74	62,630	27·96	·670	26·6	52·3	·04	·45*
		Mean ...			40,487	18·08	61,603	27·50	·657	25·3	51·6	·07	·47

* Silky. † Silky, very slight lamination. ‡ Silky, slight lamination.

COMPRESSIVE TESTS of Six Specimens cut from the Plate from which the above-numbered Flue Tube was made.

Test No.	Marks on Piece.	Dimensions. Broad.	Thick.	Area.	Buckling Load. Lbs. per sq. in.	Tons per sq. in.	Compression on 10 in. Length. 20,000 lbs. per sq. in.	30,000 lbs. per sq. in.	Buckling Load per sq. in.
NOT ANNEALED.									
18,876	2,833 P.S.	1·492	·535	·798	34,600	15·45	·02	·03	·09*
18,877	"	1·492	·538	·803	34,400	15·36	·02	·03	·08*
18,878	"	1·492	·542	·809	32,990	14·73	·02	·04	·07*
		Mean			33,997	15·18	·02	·033	·08
ANNEALED.									
18,879	"	1·497	·540	·808	37,250	16·63	·02	·03	·05
18,880	"	1·496	·542	·811	37,710	16·83	·02	·03	·06
18,881	"	1·496	·545	·815	36,350	16·23	·03	·04	·05
		Mean			37,103	16·56	·023	·033	·053

* Gave way by buckling without cracking in all cases.

NOMINAL THICKNESS, $\frac{9}{16}$ INCH.—NO. 4,296.

	Measurements taken at A.		Measurements taken at E.		Measurements taken at H.		Length.	
	Vertical.	Horizontal.	Vertical.	Horizontal.	Vertical.	Horizontal.	Right.	Left.
Measurements taken before test	Inches. $32\frac{9}{32}b$	Inches. $32\frac{1}{32}$	Inches. $32\frac{1}{64}$	Inches. $32\frac{6}{32}$	Inches. $32\frac{8}{32}$	Inches. $31\frac{31}{32}$	...	...
Pressure in lbs. per square inch.	Movement.		Movement.		Movement.		Extension on $78\frac{3}{4}$ inches.	
100	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
200	"	"	"	"	"	"	"	"
300	"	"	"	"	"	"	"	"
400	"	"	"	"	"	"	"	"
500	$\frac{1}{32}$ in.	"	$\frac{1}{32}$ in.	"	$\frac{1}{32}b$ in.	"	"	"
600	"	"	"	"	"	"	"	"
700	"	"	"	"	"	"	"	"
800	"	"	"	"	$\frac{1}{32}f$ in.	"	$\frac{1}{32}$ in.	$\frac{1}{32}$ in.
900	$\frac{1}{32}f$ in.	"	$\frac{1}{32}f$ in.	b in.	"	"	"	"
1,000	"	"	"	"	"	"	back to original.	
0	Pressure released to zero.		No permanent set.					
1,100	$\frac{1}{16}$ in.	$\frac{1}{32}b$ in.	$\frac{3}{64}$ in.	$\frac{3}{32}$ in.	$\frac{1}{16}$ in.	"	"	"
1,200	$\frac{1}{8}$ in.	$\frac{3}{32}b$ in.	$\frac{3}{64}$ in.	"	"	$\frac{1}{32}$ in.	"	"
1,340	Collapsed gradually on flat and first corrugation, front end.							
0	$30\frac{24}{32}$ in.	$31\frac{24}{32}$ in.	$31\frac{24}{32}$ in.	$32\frac{10}{32}$ in.	$32\frac{8}{32}$ in.	$31\frac{10}{32}b$ in.	"	"

NOMINAL THICKNESS, $\frac{9}{16}$ INCH = ·5625.—NO. 4,296.

Measurements for Thickness.

No. of Test Hole.	Front.	Middle.	Back.
1 weld.	·593	·589	·606
2	·557	·577	·558
3	·553	·572	·575
4	·559	·571	·563
Mean of unwelded plate	·556	·573	·565

Mean thickness of front end of plate	·556
" " middle " "	·573
" " back " "	·565
" " the plate	·567
" " the welded portion of the plate ... ... being ·0320 greater than the mean thickness of the unwelded plate.	·596
" " the unwelded plate was ... ... or ·0045 greater than the nominal thickness.	·567

Mechanical Tests of Material.—No. 4,296.

Tensile Tests of Six Specimens cut from the Plate from which the above-numbered Flue Tube was made.

Test No.	Marks on Piece.	Dimensions.			Limit of Elasticity.		Breaking Load.		Ratio of Limit to Break.	Extension on 10 in. Per cent.	Reduction of Area. Per cent.	Extension on 10 in. at	
		Broad.	Thick.	Area.	Lbs. per sq. in.	Tons per sq. in.	Lbs. per sq. in.	Tons per sq. in.				40,000 lbs. per sq. in	50,000 lbs. per sq. in.
Not Annealed.													
18,911	4,296 P.S. B. 583	1·494	·532	·795	40,000	17·86	61,310	27·37	·652	24·7	53·8	·13	·39*
18,912	"	1·494	·542	·810	38,350	17·12	61,010	27·24	·629	26·4	51·8	·20	·47†
18,913	"	1·490	·549	·818	37,870	16·91	59,720	26·66	·634	26·4	54·9	·18	·44*
		Mean ...			38,740	17·30	60,680	27·09	·638	25·8	53·5	·17	·43
Annealed.													
18,914	"	1·485	·552	·820	36,890	16·47	57,550	25·70	·641	23·7	54·1	·31	·65†
18,915	"	1·485	·548	·814	35,520	15·86	55,660	24·85	·638	27·0	55·8	·32	·76†
18,916	"	1·485	·552	·820	38,050	16·99	58,370	26·06	·652	25·1	55·9	·30	·70†
		Mean ...			36,820	16·44	57,193	25·54	·644	25·3	55·3	·31	·70

* Silky, very slight lamination. † Silky.

Compressive Tests of Six Specimens cut from the Plate from which the above-numbered Flue Tube was made.

Test No.	Marks on Piece.	Dimensions.			Buckling Load.		Compression on 10 in. Length.		
		Broad.	Thick.	Area.	Lbs. per sq. in.	Tons per sq. in.	20,000 lbs. per sq. in.	30,000 lbs. per sq. in.	Buckling Load per sq. in.
Not Annealed.									
18,917	4,296 P.S. B. 583	1·495	·535	·800	38,650	17·26	·02	·03	·06
18,918	"	1·496	·540	·808	34,850	15·56	·02	·03	·06*
18,919	"	1·498	·543	·813	33,130	14·79	·02	·03	·06
		Mean			35,543	15·87	·02	·03	·06
Annealed.									
18,920	"	1·494	·533	·796	34,940	15·60	·02	·03	·05
18,921	"	1·494	·537	·802	32,250	14·40	·03	·04	·07*
18,922	"	1·494	·540	·807	33,820	15·10	·02	·03	·06
		Mean			33,670	15·03	·023	·033	·06

* Buckled without cracking.

DISCUSSION.

Mr. ALEX. TAYLOR said he thought the Institution would warmly thank Mr. Morison for his valuable paper. He wished particularly to thank him for his condemnation of the use of hard steel for furnaces. It appeared to him that if the paper did nothing else than this, it was well worth the trouble and expense both to Mr. Morison and to them as an Institution. This hard material must have caused untold annoyance and expense to shipowners, boiler builders, and all concerned. The paper advocated a particular patent furnace, and naturally they expected to be shown all its good points. There was no doubt that it was a good furnace, but he thought Mr. Morison had been too hard upon what he (Mr. Taylor) might term the "original plain furnace." It would have been as well if certain paragraphs had been left out. For instance, it was not correct to say that for plain furnaces "the greatest thickness allowed by the Board of Trade was $\frac{5}{8}$ths of an inch." Mr. Morison asks—"Do these thick furnaces"—of course referring to plain furnaces—"of small diameter result in the maximum obtainable efficiency in a modern steamship?" But why should a thick furnace be of small diameter? It did not necessarily follow, for he had plain furnaces running 41 inches diameter at 160 lbs. working pressure. Then, again, he said—"And as the keen competition in shipping demands that, for success, attention should be given to every detail, it is necessary that a furnace should be not only the most economical for steam producing, but should be of such a formation as will last the greatest length of time and have the least prejudicial effect on the wear and tear of the boiler." This he (Mr. Taylor) thoroughly endorsed; but thought the shipowners' and boiler builders' experience of patent furnaces within the last few years did not warrant the belief that they would last "the greatest length of time and have the least prejudicial effect on the wear and tear of the boilers." Mr. Morison also said—"The material of a furnace is subjected to greater variations of temperature than in any other part of the boiler, being greatest in amount above the grate bar and least below. Intensity of temperature above the grate bar depends on the condition of the fire, the thickness of the plate, the amount of deposit on the plate, and the steam pressure." If a plain furnace is compared with any pocketed patent furnace it will at once be seen that the latter must gather the larger amount of deposit just where the flame must be most intense, as admitted later in the paper. He also further said—"The variations of temperature are incessant, and depend on condition of fires, opening and

shutting of doors, and cleaning of fires. These variations of temperature result in expansion and contraction producing definite mechanical movement, and if the design of the furnace is such that it cannot readily adapt itself to those movements (and no plain furnace can) either the material becomes distressed, or such strains are produced on the boiler that leakage results. This would appear to be a reason why corrosion at the firebar level in plain furnaces is often found to be greater than in corrugated furnaces, as in the former case the furnace is rigid and the material is subjected to more severe strains than in the case of a furnace which has greater elasticity." They all knew that, under certain conditions, furnaces pit along the line of firebars and in the way of the bridges. He had seen both *plain* and *patent* furnaces pitted right through at the firebars. He was sorry to say he could show Mr. Morison patent furnaces severely pitted along the firebar line running at the present time. Such statements as those he had quoted were scarcely fair, in his opinion, to plain furnaces. The corrosion along the side of the furnace in the line of the firebars was produced by causes other than the form of furnace, or the difference of temperature between the top and bottom of the furnace; he could go into the cause, but he did not think the paper warranted them taking up that particular question. Mr. Morison confesses to defects in Fox's furnaces. He says—"Theoretically, the Fox furnace approaches perfection" (probably if they had absolutely pure water it would), "but practically, however, it has defects, the chief of which is the undue accumulation of deposit in the narrow cavity formed by the inward corrugations, and as these corrugations are nearest to the fire the material becomes unduly heated and frequently cracks. The scale in these narrow cavities is also difficult to remove and often but imperfectly removed, thus intensifying the danger of accident." He (Mr. Taylor) was glad that at last it was admitted that these defects existed; but many engineers had been like "voices crying in the wilderness." Mr. Morison had done a great deal if he had made a furnace that was free from these defects, not one of which could be laid to the plain furnace. There were many features in the paper he should have liked to have touched upon but time would not permit. Mr. Morison admitted that the least internal diameter was a measure of the effective width of grate. They knew that, as a rule, when any of these patent furnaces were put into a boiler they took a larger amount of space than an ordinary plain furnace, and increased the cost of the boiler considerably. Probably all of them had seen a circular issued by the Leeds Forge Company practically showing Plate XXVII. and Plate XXXVII., the latter is the complement of Plate XXVII., and is a

portion of a boiler front with Mr. Morison's furnace. The dark line represents the mouth of the furnace, and the inner light line is the least or inner diameter which, of course, measures the width of grate. Now, suppose for the sake of argument that instead of patent furnaces they put in plain furnaces, keeping the same spaces as before between the shell and furnace mouth and also between the furnaces. The position of the plain furnaces are shown by the dotted circles; it will be seen that the centre furnace is lower, and the wing furnaces are about 6 inches lower; therefore, probably, another row of tubes might be put in, increasing the heating surface considerably with the same grate and shell, or if the original heating surface was sufficient, the shell might be reduced, making a smaller and less costly boiler. He would give an instance where this was done. The drawings of one set of boilers were submitted to him for approval, the contract and design of the boiler provided for patent furnaces. He said to the engine builders: "I have nothing to say against your designs; but what allowance will you make if we accept plain furnaces instead of patent, keeping the inside diameter the same, so that the grate width will not be altered, but the shell may be reduced after providing for the original amount of heating surface and water spaces? The allowance offered was £500. The owners accepted the boilers with plain furnaces; they saved £500, and he believed the boilers were more able to stand the wear and tear of ordinary work than if fitted with any patent furnace. There was just another point he would like to mention, and that was the temperatures. The diagram shows the results of the late Dr. Kirk's experiments. The experiments could not be called delicate or exact, but were carried out by placing a cup-like vessel, the bottom of which was originally 2¾ inches thick, and through which an ordinary 2½ inch boiler tube was driven and made tight, as in an ordinary boiler, and carried up through the centre of the cup. The vessel was placed on a blacksmith's fire and allowed to remain about three-quarters of an hour with the blast on, and the result noted in each case. Dr. Kirk did not say the results were any indication of the heat in a furnace crown, and neither can we. It might be good for the particular object he had in view, but it could be no indication of the heat in a furnace crown. The curve was supposed to show the difference of temperatures between the water and the face of the plate exposed to the fire. This, of course, is not the difference of temperature of the two faces of the plate. But the most curious thing about this curve is that in all respects it differs from the results given in Dr. Kirk's first letter in *Engineering*, July 15th, 1892,

wherein he gives the result of his experiments as far as they had been carried at that time. In the first experiment, with the bottom $2\frac{3}{4}$ inches thick, he said "they could say in round figures that the temperature of the end of the tube was about 1,000 degs." In No. 2 experiment, with the bottom $1\frac{3}{4}$ inches thick, "the temperature was over 600 degs. and under 1,000 degs., perhaps they should not be far wrong if they put it down about 700 degs." In the third experiment, with the bottom plate $1\frac{1}{4}$ inches thick, "the temperature was between 450 and 600 degs., probably nearly 600, because when repeated with a little oil present the temperature was a little over 600 degs." In the fifth experiment, with the bottom plate 1 inch thick, "the temperature was probably about 500 degs." In the sixth experiment, with the tube plates $\frac{15}{16}$ inch thick, "the temperature must have been about 440 degs., and where $\frac{3}{4}$ inch thick, below that." In reducing the plate the turner had tapered the plate for this experiment. After the publication of the letter from which these quotations are made, Mr. Yarrow, he believed, wrote asking Dr. Kirk to continue his experiments on thinner plates, as by so doing thin plates would be found most suitable for tube plates. Dr. Kirk then continued his experiments with plates $\frac{5}{8}$ and $\frac{1}{2}$ inch thick. It seemed surprising that Dr. Kirk should depart from his first letter in making the curve shown on the diagram. If he had put in a curve to suit the temperature given in his first letter, it would have been almost a straight line, and in accordance with our present knowledge, for it is generally believed that internal temperature increases directly as the thickness. Further, if Dr. Kirk's curve is correct and is continued, it will be found that with a $\frac{3}{8}$ inch plate the water should be as hot as the plate surface exposed to the fire, and if the plates were less thick the water should be hotter than the plate exposed to the fire!

The President hoped that at their next meeting, to be held at Sunderland, on January 13th, they would have a good muster of members. He was quite sure, if this evening was an indication, the discussion would be very valuable to their Institution.

The meeting then adjourned.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

NINTH SESSION, 1892-93.

PROCEEDINGS.

FOURTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUBSCRIPTION LITERARY SOCIETY, FAWCETT STREET, SUNDERLAND, ON FRIDAY, JANUARY 13TH, 1893.

ROBERT THOMPSON, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting, held in Newcastle-upon-Tyne, on December 14th, which were approved by the members present and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. H. Macoll and J. R. Fothergill to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Dykes, George, Shipbuilder, 34, Lloyd Strasse, Bremerhaven.
Middleton, H., Steel Manufacturer, Tyne View House, Whickham, Durhamshire.
Orlando, Chev. Giuseppe, Naval Architect, Cantiere Navale, Fratelli Orlando, Leghorn.

GRADUATES.

Carpmael, Richard Herbert, Apprentice Engineer, 54, Maple Street, Newcastle-on-Tyne.
Clarke, John H., Engineer, 5, Gordon Terrace, Southwick, Sunderland.

ACKNOWLEDGMENT OF A BENEVOLENT DONATION.

The SECRETARY read the following letter to the President :—

SHEFFIELD, *December* 31*st*, 1892.

DEAR SIR,—I have the pleasure to communicate to you a resolution unanimously passed at a meeting of the Atlas Works Sick Club, on Friday, the 23rd instant :—"That the best thanks of the meeting be given to Robert Thompson, Esq., and to the North-East Coast Institution of Engineers and Shipbuilders for the generous donation of £10 towards the funds of the Atlas Sick Society." Enclosed I send you a copy of the last balance sheet,—And am, your obedient servant,

W. EYRE,
Secretary of the Sick Club.

PRESENTATION OF GOLD MEDALS.

The PRESIDENT expressed the pleasure he had in presenting the medals to Mr. Jennings Campbell and Mr. M. C. James awarded by the Council for their papers read last session, as intimated at the previous meeting. Mr. Jennings Campbell's paper was "On Engines for Ships of War," and Mr. M. C. James's "On Tonnage Measurement." The recipients acknowledged the satisfaction they had in receiving the gold medals of the Institution.

The discussion on Mr. D. B. Morison's paper on "Marine Boiler Furnaces" was resumed.

ADJOURNED DISCUSSION ON MR. D. B. MORISON'S PAPER ON "MARINE BOILER FURNACES."

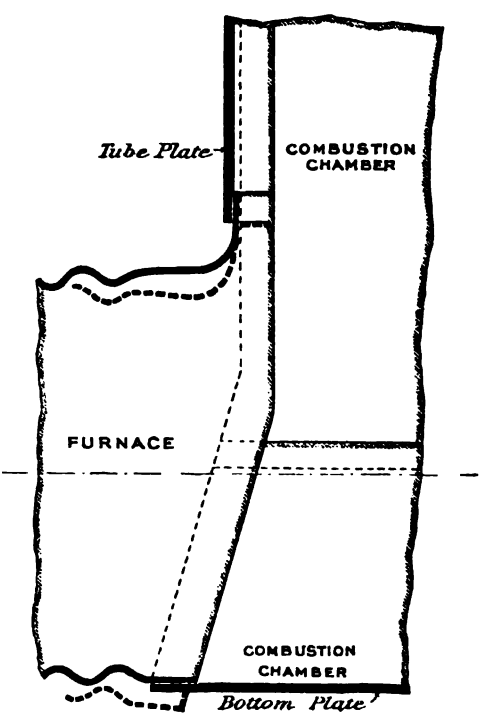
The SECRETARY intimated the receipt of several communications on Mr. Morison's paper on "Marine Boiler Furnaces," and which he was authorised to read as part of the discussion.

The first was from Mr. H. Compton Ashlin, who, although not a member of the Institution, had had his plan of putting in furnaces referred to in the paper, and the letter was accompanied by a small model and a drawing.

COMMUNICATION FROM MR. H. COMPTON ASHLIN.

DEAR MR. DUCKITT,

As I do not expect to be present at the discussion of Mr. Morison's paper on "Furnaces," I would take it as a favour if you would kindly place the following before the meeting:—Mr. Morison, after reading his paper on "Furnaces," informed me that he had been asked if my plan of furnace (interchangeable) could be applied with the flange at the back end of the furnace fitted to the combustion chamber or fire side of the tube plate. My reply was "certainly," provided the bottom of the combustion chamber is made with a separate plate taking the sides of the combustion chamber, in which case the mode of drawing the furnace is as follows:—Cut loose and drop the bottom of the combustion chamber,



out loose the furnace and drop its back end until the flange of the furnace clears the tube plate (some 3 inches is all that is necessary), then draw it out in the usual way; replace the new furnace in the same manner, lift it up into its place in connection with the tube plate, and replace the bottom of the combustion chamber; or if it is not considered worth while to go to this trouble, the furnace flange can be fitted to the combustion chamber side of the tube plate in the first place, and then only in the case of renewing the furnace would it become necessary to fit the flange against the water side of the tube plate, in which case, when desired to remove a damaged furnace without cutting a combustion chamber, it would be necessary to cut the damaged furnace out, and in replacing it with a new and entire furnace the furnace would now have to be fixed with the flange against the water side of the tube plate as shown on Mr. Morison's drawing (Plate XXVII). The illustration here given will explain the method described. The black line shows the furnace in place with the flange on the combustion chamber side of the tube plate; the dotted line shows the furnace, etc., cut loose and dropped into position for drawing clear of the tube plate.

Yours faithfully,
H. Compton Ashlin.

Communication from Mr. A. Rolland, Superintendent Engineer of the Royal Hungarian Steam Navigation Company.

Dear Mr. Duckitt,

I am sure that anyone reading Mr. Morison's paper must be struck with the amount of research and thorough study of the technical part of the question it displays, and I for one thank him very much for the information given. On the other hand, I should require to hear a little more of the practical working experience with his form of furnace before I should adopt it. I think you will agree with me when I say that there are very few, if any, established cases of a furnace having failed for want of strength against a compressive strain, unless there were other circumstances contributing to it, such as dirty crowns, etc.; consequently, I should say that this shows that the factors of safety as required by Lloyd's and the Board of Trade are sufficiently high in any of the cases put forward by Mr. Morison. So far as I understand, Mr. Morison does not combat this part of the question, but if I understood his meaning

rightly when he was reading his paper he would like us to believe that by using his form of furnace we ought to be entitled to use a thinner plate for the same pressure and diameter than we should use in any of the present forms. Allowing this to be just, under cold water testing, what are the practical working conditions of the various forms? I may here state that I have had steamers running under my superintendence for years, running for 36 and 38 days' steaming, and touching various ports, without evaporators and with them, and boilers fitted with Fox's corrugated, plain, and with Purves's ribbed flues, all at 160 lbs. pressure per square inch. After one of these voyages I find that the bottom of the corrugations in Fox's are full of layers of scale: this is caused, I think, by the cooling action which takes place at the various ports of call when the fires are damped, causing the scale to crack off and slide down into the corrugation, thus thickening the scale at the place where the flame strikes hardest, and in some cases I have no doubt this is the cause of collapsed furnace crowns. Of course it might be said that by the use of a good evaporator this could be avoided, but we must never forget that with a careless engineer our evaporator may be useless. What I fear in the Morison furnace is that it being made in curves (not so short, it is true) the same thing might happen, and in that case you would run the risk of overheating the plate much sooner than you would with a plain flue, or with flues like Holmes's, Purves's, or Adamson joint; in other words, you would have the highest factor of safety under the cold water test, but you would not have it under the working conditions; the scale in the case of the plain flues, Holmes's, and Purves's, falling down the sides of the furnace into the bottom of the boiler, or simply remaining in place. In regard to the opinion Mr. Morison has expressed that the steel presently being used for furnace construction is of too high tensile strength, I think all practical men hold the same opinion; but do you not think that this has arisen a good deal from the desire of the various makers to show a high factor of safety under the cold water test, and in fact partly what Mr. Morison himself is trying to show us in his own paper? I would only say in finishing that it is a pity Mr. Morison could not have tested flues of his form more nearly in diameter with some of the others, as though they are all brought down to a common ratio, yet I hardly think we can say they are an exact comparison. However, as I said before, we must all thank him for the amount of information he has given us.

Yours faithfully,

A. ROLLAND.

COMMUNICATION FROM Mr. W. A. F. CRAWFORD.

DEAR MR. DUCKITT,

In dealing with Mr. Morison's paper on this subject I propose, without prejudice, to take full advantage of the author's invitation to discuss it broadly.

Temperature.—With the object of showing what the temperature may be in the interior of a plate forming part of the heating surface of a boiler, the writer relies on certain experiments made by the late respected Dr. Kirk, as reported in *Engineering*, on July 15th and September 9th, 1892. These experiments were reasonably designed with the object in view, viz., to show that the tube end next the combustion chamber may

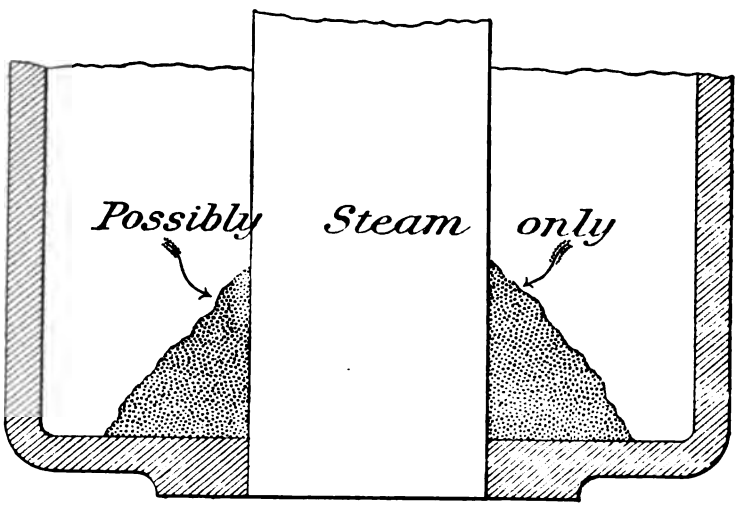


Fig. 1.

rise to a very high temperature, and that this varies considerably with the thickness of the tube plate, *i.e.*, the thinner the plate the lower the temperature, all other things being equal. They were not, so far as the experimenter explains his object, intended to determine even approximately the temperature inside a plate in its function as part of the heating surface of a boiler, nor is it even probable that a man gifted with his sense would accept the result as even approaching it. All they sought to do was to determine within certain limits the temperatures in the vicinity of the plugs, and probably to show that the tube ends were at a higher temperature than the plugs, but as there was a surface between the plate and the plugs it is fairly certain that the plate was at a much lower temperature than that recorded. It is also worthy of note that the

apparatus was over a forge fire, and, as the experimenter says, at a temperature much higher than it would be even with forced draught, the evaporation must have been very rapid, and possibly the water in the vicinity of the tubes nearest the fire was in a spheroidal condition, particularly when oil was added to the water. (See Fig. 1.)

Through the courtesy of Mr. A. Blechynden I am able to lay before you records of some experiments, which, though probably not carried so far as he intends, yet bear with sufficient directness on the point as to leave

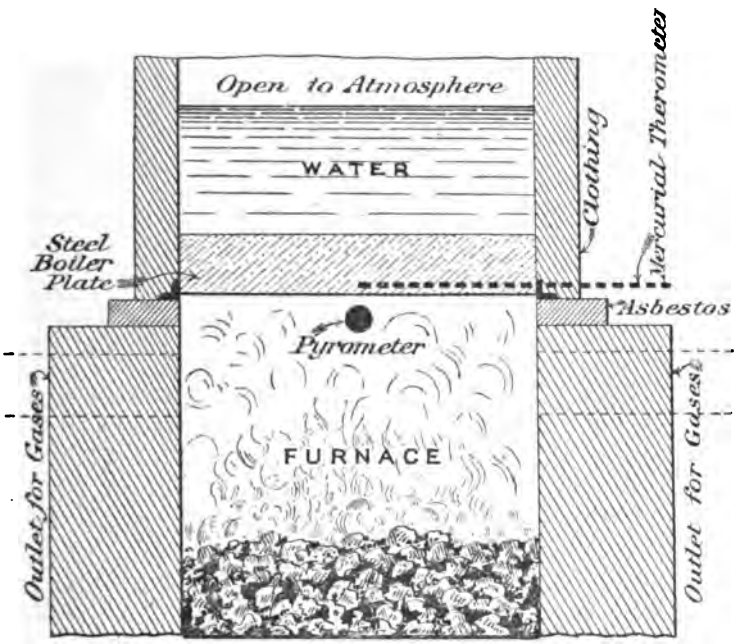


Fig. 2.

no doubt that the temperature in the interior of the plates forming the heating surface of the boiler are much lower than those stated by the author of the paper, always assuming, as the author does, that the surface of the plates is clean. The apparatus used for the experiments was of a very simple character and will be easily understood from the illustration (Fig. 2). The fire was composed of asbestos lumps heated with blowpipes placed beneath them. Mr. Blechynden writes me as follows:—

January 6th, 1893.

DEAR MR. CRAWFORD,—In reply to your query respecting the temperature in the interior of boiler plates while performing their function as heating surface, I can give you some information on the subject as you surmise. Sketch of apparatus herewith. The temperatures of the furnace are based on the Pouilett determination

of the specific heat of platinum. The plate was 1·15625 inches thick, the holes for the thermometer were 0·25 inch diameter, and the lowest had 0·03125 inch of thickness between its bottom and the surface next the fire.

The following are some of the results of temperatures taken at the bottom station :—

Temperatures Measured.			Difference of Temperature.		Calculated Difference between Plate and Water.
Furnace.	Plate.	Water.	Furnace and Water.	Plate and Water.	
Degs. Fah.	Degs. Fah.	Degs. Fah.	Degs. Fah.	Degs. Fah.	Degs. Fah.
890	234·5	210·5	679·5	23	22·5
1,016	242	212	804	30	31·6
1,038	246	212	826	34	33·35
1,095	250	212	883	38	38·2
1,230	263	212	1,018	57	50·6

The calculated differences in the last column are made from :—

$$\frac{(\text{Temperature of furnace} - \text{temperature of water})^2}{\text{Temperature of plate} - \text{temperature of water}} = 20{,}482. \ (a.)$$

It should be noted that the temperatures of the furnace as given above are not those of the incandescent portion of the fire, but practically the temperature of the escaping gases. The temperatures, about 1·5 inches over the asbestos fire, would in all cases given be about 25 per cent. higher than those in the table, as found by the experiments.

The formula (a) is based on the fact that the rate of transmission of heat through a plate, as in a boiler, is proportionate to the square of the difference of the temperatures on the two sides, which I have found to be practically accurate. The true figure for the modulus as found by (a) should be :—

$$\frac{(\text{Maxim. temp. furnace} - \text{temp. water}) \times (\text{temps. escaping gas} - \text{temp. water})}{(\text{Temperature of plate} - \text{temperature of water})} = \text{a constant,}$$

which in this case is 20,482 × 1·25 = 25,610.

There were also temperatures measured at a point 0·625 inch and 0·25 inch from top surface of plate. The latter temperatures were about 0·6 of those given for the bottom. The former was somewhat lower than an arithmetical mean between the others. And it appears as if the extremes of temperature in the plate might fairly be estimated from a diagram whose ordinates were the temperatures measured at the upper and lower points and the abscissæ the thicknesses. Thus, for the furnace, temperature 1,230 degs. Fah., I should expect the extremes, 235·5 degs. Fah. and 268 degs. Fah., and the difference of temperature over the plate, 32·5 degs. Fah., a very insignificant difference for so thick a plate.

I trust this may serve your purpose, and you are at liberty to use it as you please.

Your truly,

A. BLECHYNDEN.

P.S.—It is not my intention to enter into a discussion of the paper referred to.

Fig. 3 is the diagram referred to towards the end of this letter.

The experiments above quoted are, it will be seen, essentially measurements within the plate, and admit of no doubt.

Now, to take, say, an 1·15625 plate in juxtaposition to a fire 2,000 degs. Fah., and assuming the temperature of the water 212 degs. Fah., its temperature at the point next the fire, *i.e.*, 0·15625 from the surface might reasonably be expected to be:—

$$\frac{(2{,}000 \text{ degs.} - 212 \text{ degs.})^2}{25{,}610} + 212 \text{ degs.} = 336{\cdot}8 \text{ degs. Fah.},$$

or at the surface probably 349·8 degs. Fah. instead of the temperatures 670 degs. Fah. and 468 degs. Fah., which the writer gives for an inch and a ½ inch plate respectively, while if the same modulus of transmission holds for higher temperature of plate, and the water is at 380 degs. Fah., this temperature would not exceed—

$$\frac{(2{,}000 - 380)^2}{25{,}610} + 380 = 482 \text{ degs. at } 0{\cdot}15625$$

from surface, or about 491 degs. at surface next the fire.

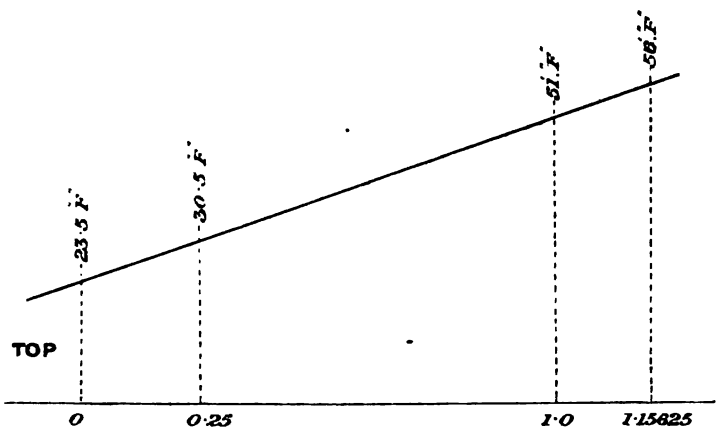


Fig. 3.

Mr. Morison introduces the subject of internal temperatures in its bearing on the elastic and ultimate tensile strength of the material only, and endeavours to show with the help of the data furnished by the experiments made by the American Government that at the temperatures he estimates to exist in the interior of furnace plates their strengths are not materially reduced.

This view of the matter, however, is only of small importance compared with the question of the internal stresses in the structure caused by local variations of temperature, especially if complicated with irregularity of form.

Tables are given in the paper of experiments made to ascertain the collapsing strength by external fluid pressure of various forms of furnaces,

apparently with the object of showing that the "suspension" form of furnace is the best. But it would be as well to note that it appears as if results had progressively increased in value relatively to the advance of time, indicating that more recent methods of manufacture had a good deal to do with higher coefficients.

It is also stated in effect when contrasting the strength of the suspension and the ribbed form of flues, that the thinner the latter the better is the coefficient. While this may probably have been correct at the time these experiments were made, it does not follow that it is still true, and I have it on the authority of Mr. Purves "that at first machinery had not been put down to round the thick ones properly," which is the requisite and sufficient explanation. It is therefore not unreasonable to assume that the next trials made by Messrs. Brown will show an increased coefficient over any previously obtained.

Now, while it is true that the Board of Trade and Lloyd's have set up the hydraulic test as a standard, and it is probably the best these bodies can do under the circumstances, our eyes cannot possibly be shut to the fact that, while these tests determine the relative strength of the structure to resist compression by the action of uniform external fluid pressure, they do not by any means determine the true relative merits of the structures as boiler flues when in addition to the external pressures they are exposed to the internal stresses, already referred to, due to the unequal temperature at their various parts, which, while such as may be generally foreseen, are in the present state of our knowledge utterly impossible to determine quantitatively. I therefore think that the question of internal temperature, which the author has so readily dismissed, is the most important factor which will operate in selecting the most suitable form of furnace; in other words, the only thorough test is practical experience with the various forms in ordinary working.

Now, referring to practical work, the author makes this statement on page 114: the "Purves flue is not so strong as the Fox to resist collapse, whilst its unequal section and longitudinal rigidity localise the stresses resulting from variation of temperature, an evidence of which is the occasional development of cracks either by circumferential ripping at the base of the rib or in the vicinity of the flanges at the back end." The writer here appears to realise the importance of local internal *stresses*.

He does not say that similar accidents have ever occurred with the corrugated type, under which head the suspension may be classed, but leaves it to be inferred that there had not. So far as my enquiries have extended I have not found that the ribbed form has exhibited more ten-

dency to such defects as those instanced, and the makers absolutely deny that the cracking at the base of a rib in a Purves flue has ever come under their notice, and as Mr. Morison has not supported his statement by facts it now behoves him to prove this portion.

I have before me the facts in connection with the failure of certain furnaces in one of H.M. second-class cruisers, built under the recent Naval Defence Act. Cracks developed in the furnaces in the vicinity of their junction with the combustion chambers. As these were ribbed furnaces the case might appear to support the author's statement if it stood alone; unfortunately, for his position, the case was not altogether singular, and precisely similar defects occurred in the boiler of another cruiser of the same class, which were fitted with the Fox corrugated type of furnace. There are plenty of other facts to the same effect, and on this point therefore the evidence seems balanced and to point to some other common cause than longitudinal rigidity, most probably local heating during manufacture without subsequent annealing, which, as is well-known, is a fruitful source of failure in many furnaces.

Now, if isolated instances have to be taken in evidence, the case of the "Hecla"—a boat, I believe, not unknown in Hartlepool—might be cited, which at the time was fitted with two corrugated and one ribbed flue. The ribbed flue having replaced a corrugated flue some time previously. The two corrugated flues collapsed and cracked, while the ribbed flue stood up to its work. Subsequently ribbed flues were fitted throughout. On its face this is a strong case for the ribbed form, as it may be reasonably assumed that the furnaces being in one boiler and worked by one set of men received similar treatment.

Towards the end of the first paragraph on page 115 the author claims as a feature of the suspension furnace its uniform strength throughout and distribution of strains uniformly throughout the lengths of the furnace.

If the writer refers to the hydraulic crushing test upon the section of the metal it is certainly not uniform from end to end, but so far as can be judged from its form must vary uniformly, so that if a diagram of stresses were drawn the curve would be one generally resembling the configuration of the furnace's section; while if he refers to the stresses due to local differences of temperature, the merest tyro would say nobody knows what they are, but their chief characteristic is utter want of uniformity.

It is only fair that due appreciation should be given to the paper where it accords with fact and practical reasoning. In dealing with the question of form, while comparing those of Fox and Purves, the writer of the paper states that practically the former's chief defect is the "undue"

accumulation of deposit in the corrugations that are convex inwards, and that consequently the material becomes overheated and frequently cracks." I am of opinion that the prefix "un" should be omitted, and that accumulation of deposit on those parts is *due* partly to the form and partly to that portion of the plate being at a higher temperature than the outer curves, and that the ultimate "overheating" of the plate is entirely *due* to the scale upon its surface, aggravated probably by its close proximity to the fire. While in regard to his statement of the result, viz., the frequency of cracks, it is unfortunate that the writer is calculated to find a perfect unanimity of opinion throughout the Institution. Now, in the more nearly right circularly cylindric form of furnace to which the Purves approaches, the deposit of scale may be regarded as practically uniform throughout the length of the flats so far as their form is concerned, but non-uniform so far as they are affected by the variation of the temperature of the furnace eddies and circulation of water so that they are free from the local deposits which are the characteristics of the corrugated form.

The deposit being distributed over a wider area is therefore thinner and there is less danger of overheating from this cause alone—by overheating being understood a higher temperature in the plate than that existing when the plate has fairly clean surfaces. Therefore it will reasonably be admitted that the local internal stresses are also much reduced, as also the liability to failure.

Passing to that particular form of furnace advocated by the writer it may probably be an improvement on the old or "uniform" type, but it still retains that very serious defect of form which tends to the rapid local formation of scale, which is admittedly the worst feature of the Fox flue, though possibly this may be mitigated in some slight degree by the greater length of curve; it cannot possibly, however, while retaining the curved form of section, be so free from this defect as the Purves form, and every reason which would lead me to reject the Fox form would induce me to reject its modification in the suspension type.

As the author has carefully ignored any comparison with the existing plain right circularly cylindric form of furnace it may not be etiquette to introduce it, but as it can be clearly inferred that the elements of this criticism if carried to an ultimate issue, point to that form of furnace as the best, I may be allowed to say that, until some reliable experiments have been conducted which will show that we are safe in using a thicker furnace and the Board of Trade can be convinced of its safety, then my view is that the Purves form is by far the best compromise.

I have studiously avoided any reference to evaporative efficiency which it is difficult to prove to vary with the type of furnace fitted.

One might propound theorems on the result of the inrush of cold air on the various forms of furnaces, but as the result of practical working is, as I have confessed, our only real test, it were idle to occupy further time by adding this to the discussion.

Yours faithfully,

W. A. F. CRAWFORD.

Mr. F. GROSS (Atlas Works, Sheffield) said if they would allow him to read a few remarks he had prepared he should feel much obliged, and he trusted they would consider they were not in any way trying to discuss the matter in an unfriendly spirit to Mr. Morison, whom they all respected. Representing the makers of one of the furnaces under discussion this evening, he requested permission, and was obliged for the opportunity, to say a few words on behalf of the alleged delinquent, the Purves furnace. He understood that Mr. Taylor at the last meeting ably defended its grandfather, the plain furnace—a good old servant for which some engineers still show a certain fondness. Those engineers, who have the most experience with the Purves furnace, agree that it has proved a worthy successor, with additional good qualities required by the times they lived in, and this has been conceded to a certain extent in the paper before them. Everyone would admit that Mr. Morison had taken great pains in preparing this paper. It, however, was no exception to the rule that there were always more sides to any question than one, that no case was complete without the evidence for the defence, and they rather welcomed the opportunity of discussing this furnace question openly. It was allowed that the Purves furnace is stronger than a plain furnace, as strong as the corrugated, and practically even as strong as the Morison, that the flats between the ribs have the advantage of being good heat-absorbing surface on the inside, of keeping cleaner, and of being more easily cleaned than any furnace with pockets, and that the strengthening ribs are out of the fire and well up in the water. Not a small list of recommendations one would think! But on the other side comes the indictment, that the furnaces are made of steel of the quality prescribed for furnaces by the various surveys, that the ribs in the water are of greater thickness than the flats exposed to the fire as heat-absorbing surface, that the Purves furnace has actually nearly as much longitudinal rigidity as the plain furnace, and is not ashamed of it. Nothing is said of the easy repair of a flat surface, compared with a curved one, of the difficulty of keeping a patch on a curved surface tight when made, but then, of course, no furnace ever requires repairs. Mr. Morison's experience of the collapsing tendency of

the flats of the Purves furnace has been singularly unfortunate. He was afraid, and must admit that in at least one instance, the surveyor reported to his headquarters that on first entering the boiler he could not see the ribs on the crown of the furnace, although they project 1⅜ inches above the flats. Some engineers have considered that, when the deposit has been allowed to get to this depth, it was a grand testimonial for the Purves furnace, that only the flats, which can easily be put back, sagged and the ribs kept the general form of the furnace intact, but of course there are even two ways of looking at this. To their mind, however, the value of the thickened rib could not be better demonstrated. On the question of the tensile strain of the steel in their experimental furnaces he need not say more than that it was made well within the requirements of the surveys to which they had to be submitted, and that the present formulæ were obtained far more by the ultimate more perfect welding of the ribs (which was then no child's task) and by greater roundness as well as an increase in height of rib and shortening of distance of centres of ribs. In the paper it had been argued that their final success was due to the very slight difference in tensile strain between the several series. If so-called high tensile strength is such an objectionable feature in furnace steel, as represented in the paper, why was the average tensile strain of the Morison experimental flues the highest of all and the formulæ obtained on this? But these are all minor matters. The one great difference between the corrugated and Morison flues compared with the Purves, is what is called the greater longitudinal rigidity of the latter, or, as he preferred to call it, its backbone. Time was when backbone was not considered an objection. The plain furnace and the Adamson ring furnace were not considered the worse for their backbone. He ventured to think the Adamson ring furnace and the corrugated furnace were intended for greater strength and not because greater elasticity was thought desirable. The Purves furnace is an Adamson ring furnace with solid instead of riveted or welded circumferential flanges. Now, has it really been proved that the backbone of the Purves flue is such an objection? Having counted up all the Purves furnaces which have failed from any cause whatever, they found these amount to less than 1 per cent. of the whole 10,000 supplied to date. Was the percentage of the corrugated any less, and has the Morison furnace, young as it is, been free from mishaps entirely? It is satisfactory to note the change in the views regarding both effective grate and heating surface. For years the argument has been the other way against the Purves furnace, but these are now getting their due in this respect. It is probable that the opinion will also become general that

the longitudinal flexibility, too, of corrugated furnaces has been overestimated. The series of experiments made for the surveys do not show the supposed difference between corrugated and Purves furnaces, and where stands the argument if Purves furnaces are supposed to crack because of their stiffness endwise and the corrugated in spite of their supposed elasticity? Of course small as the percentage is on the whole, it is undesirable even to have this, and valuable lessons are being learned and will not be wasted. It is noticed by comparing the boiler drawings of different engineering firms, that those who keep the longitudinal stays as far away as possible from the flanges of the back end of centre furnaces, or omit them whenever they can, who keep the bottom row of tubes as far away from the crown of the furnace as possible, who single rivet the back ends of the furnaces, who agree to a liberal radius of saddle and return flange, who keep the cross stays in the combustion chamber a good distance from the riveted furnace seam, practically never have any trouble. The furnaces, which usually crack in the return flange, are in nine cases out of ten centre furnaces in double-ended boilers, and dividing the combustion chamber of opposite furnaces, by making each separate, has not cured this. A failure in a single-ended boiler is a very rare occurrence. It is not improbable, that the cross-stays have been the cause of more trouble than was suspected, but special attention is now directed to this particular point. In addition to these questions of design there is the sore point of the treatment of the furnaces by the boilermakers, and these have their own sore point in return in the treatment when the furnaces get into use. Of course the steelmakers never make bad or unsound steel, the plate and furnace makers cannot spoil a furnace in manufacture, the boilermakers never alter—in fact never touch—the furnaces when they get them, and improper treatment at sea is out of question. You will agree that the furnace makers are being pretty well looked after between their own inspectors, the several surveys, the boilermakers, the owners, and the consulting engineers, and their chances of getting an unsatisfactory furnace into use, even if they wished it, are very slight. Seriously, the furnaces now being supplied are nearer perfection with regard to manufacture than ever they have been before, and the boilermakers are more and more realising, that it is not foolishness on the part of the furnace makers to request that their furnaces supplied in a well annealed condition shall not be locally heated—even with those convenient little things called heaters, which have hitherto counted for nothing. At sea also the treatment of boilers on the whole shows a decided im-

provement. It would be a misapprehension to suppose the Purves flue under proper conditions requires any special delicate treatment because of its stiffness. Many boilermakers in this important district and elsewhere have never had any trouble at all, although they have had hundreds of furnaces each. Some of them had seen at their works the marine boilers they use, burning 50 per cent. more coal per square foot of ordinary size grate than the highest present Atlantic practice. Although he did not suggest it for their steamers, it was well they should know that they had several times stopped a high rate of combustion test, raked the fire out, run the water out, and without fear played the cold hose into the Purves furnaces to enable engineers present to go with comfort into the combustion chambers to examine the tube plates and tube ends within an hour from the stoppage, without the least trouble resulting. Much had been said in the paper about the steel now used for furnaces being too hard. That was really a misleading term, and troubles have occurred in Admiralty boilers, with corrugated and Purves flues, although the tensile strain of the material for this survey is required so low. There are boilers still at work which were made of Bessemer steel of about 40 tons tensile strain before the days of mild Siemens' furnace steel. The solution of the question of avoiding trouble from cracked furnaces does not lie in the direction of low tensile strain steel. All that this will do is to allow of rougher treatment in the boilershops, without perhaps showing then, but surely this was not what they all desired. It must not be overlooked on the other side, that low tensile strain steel is much more difficult to make sound. On the surface, roaks, which are honeycombs just under the skin of the ingot, afterwards rolled out into black lines—in reality splits of however little depth—become much more common, and by alternate frequent expansion and contraction of furnace they will become a new cause of trouble, probably more serious than the one they desired to avoid now. Tensile strength is no objection—the point is to have high ductility in every part, and repeated experiments have shown, that pieces of plate heated with heaters have lost their ductility thereby. Better work the material to a limited extent cold than heat it slightly in this manner. There is one type of back end, which the paper does not mention, viz., the one which has been used for years by Messrs. Gourlay Bros., Dundee, and Messrs. A. Stephen & Sons, Glasgow, without trouble and which should recommend itself to engineers as it did to them as makers, because fitting together of furnaces and tube plate becomes unnecessary. It has also the merit of being withdrawable through the front plate.

Mr. J. R. FOTHERGILL said he should like first of all to thank Mr. Morison for the very able paper he had put before the meeting—a paper of such value must add great weight to their proceedings, and raise the Institution in the estimation of the engineering world. The paper was of such a very lengthy description, that it was impossible to do more than touch upon one or two points. He had listened with great pleasure to the very able criticism of Mr. Gross, who, not only as representing the important firm that he did, but as a very large manufacturer of furnaces, unquestionably spoke with considerable authority. Naturally, he felt the responsibility in disagreeing with what they had heard Mr. Gross put forth as to the value of high tensile steel, but he was obliged to say his experience, and it had been an expensive one, led him to believe high tensile steel was not a proper material for the manufacture of furnaces. In dealing with the transmission of heat through plates, it was desirable to use a thin plate in preference to a thick one. He freely admitted there were distinctive features of advantage in the plain furnace so strongly advocated by Mr. Taylor, yet he was of the opinion, if by special design they could get the necessary strength, without introducing consequent evils, it was desirable and advantageous they should do so. But he most emphatically objected to the use of thin plates in which their strength depended on the use of a high tensile material. Special designed furnaces of the past had not proved as effective as was generally anticipated; but he held this should not debar an endeavour by improved design to produce an efficient furnace. He thought it would be conceded an efficient furnace should be manufactured of such material that under no possible conditions could it crack. He failed to see that it was any excuse to say a furnace cracked because it was allowed to become overheated, due to neglect or otherwise. The material should be of such a quality that by overheating the crown might come down even to the bars, yet it should not crack. It was this liability to cracking, the unfortunate experience of late years, that shook one's confidence and offered such serious consequences. Undoubtedly, this cracking was principally due to the use of high tensile steel. He saw Mr Gross shake his head. Well, he was sorry he could not agree with Mr. Gross. To show the form of cracking he had there a sample cut from a Purves flue. The steamer arrived in the United Kingdom off an Indian voyage, and was in port nine days discharging, during which time the boilers were opened out and examined and no defects noted. The day before the discharging was finished the boilers were being filled from a water boat with fresh water. When the water had risen in the boiler to about the level of the

top of the furnace crowns (single-ended boiler, two furnaces) the starboard furnace cracked circumferentially in the rib with a loud report. An examination of the crack showed it extended from about 4 inches below the top of the bars to some 16 inches above the bars. The crack was sharp and clean, and perfectly free from any sign of corrosion. If they would examine the material they would see it was of a very hard and high tensile kind. The next sample was also a very interesting one. It was likewise taken from a Purves flue. The steamer had been discharging in port, and after getting up steam and making a few turns of the engines banked fires, when immediately the crack occurred. It would appear the immediate cause of these cracks was variation of temperature: in the first case due to the cold water, and in the second case due to banking the fires. If this was the explanation, then the material at the point of fracture must have been in a very high state of tension; but he assumed this could not occur in low tensile steel, therefore he concluded such evidence strongly condemned the use of high tensile steel. The cases referred to were not by any means isolated cases, for many cases had come under his observation. In condemning high tensile steel, they must be careful not to rush to the other extreme. Low tensile steel very frequently in manufacture showed on the surface slight cracks or splits, which might possibly extend, and undoubtedly these cracks offered great facilities to corrosion. The peculiar feature about cracking was that it usually took place circumferentially in the Purves flue, and longitudinally in the Fox. The cracking in the Fox flue mostly took place at about 4 inches above the line of firebars on the inner corrugation to the fire. The cracks commenced on the water side and took some little time to develop and extend through the plate. They appeared to be a combination of crack developed by corrosion until the plate became so thin that it finally cracked through. He had there a sample cut from a Fox furnace, which, if they examined, they would see several cracks had taken place, penetrating the plate to various depths, one completely through. These cracks on the fire side were usually from $\frac{3}{4}$ inch to 2 inches in length, and when the water was out of the boiler, most difficult to find, *i.e.*, on the fire side, as shown by the sample. Fortunately, these cracks are easily secured by studding. Mr. Gross referred to the question of repairs. This was undoubtedly an important matter, and one not to be treated lightly, for from one cause or another it was occasionally necessary to patch a furnace. Unquestionably, the plain furnace was the simplest to patch, and therefore the most reliable repairs could be made, providing you had not to deal with the "lapping" of excessively thick plates in

the direct heat of the fire; but the Purves furnace as well as the Fox could be patched, although he had always found it required most thoroughly experienced workmen to execute reliable patching, and more particularly so with the Fox. He had his own boilersmiths, and felt no hesitation in putting a patch on either a Purves or Fox to run for twelve months. Mr. Morison was perfectly right in saying a furnace should be of such design that no pocket or recess existed to facilitate deposit. This was a weak feature in the corrugated furnace, as deposit soon took place on the inner corrugation. The Purves furnace was not so bad, in fact it compared more with the flat furnace in that respect. The question of longitudinal elasticity which Mr. Morison had referred to at some length, and which Mr. Gross had also spoken to, was open to considerable argument, and much might be said as to the present system of staying as required by the Board of Trade and Lloyd's; but as he wished to make a remark or two on the question of corrosion, he would leave this subject to others, and hoped to hear it fully discussed. As to the question of corrosion or pitting on the sides of furnaces, Mr. Taylor, in his remarks, had said:—"The corrosion along the sides of the furnace in the line of the firebars was produced by causes other than the form of furnace, or rather difference of temperature between the top and the bottom of the furnace." The difference of temperature between the top and the bottom of the furnace, he (Mr. Fothergill) did not think would have a material effect, providing it was a regular gradation in temperature, but that was altogether a different matter to rapid and sudden variation of temperature in the immediate region of the fire. He thought the following illustration would show the effect of variation of temperature. During his forced draught experiments, he observed, as he increased the length of the firebars from 2 feet 6 inches to 3 feet, then to 3 feet 6 inches and to 4 feet, the position of signs of pitting or corrosion varied with the altered length of the bars, or in other words, altered as the position of greatest variation of temperature was altered. He did not say that variation of temperature was the whole cause of the pitting referred to, but it certainly had a material effect on the question. There was just one other matter, and that was, he wished to say he most fully agreed with Mr. Morison and Mr. Taylor that the inner diameter of the furnace should be taken as the breadth of the grate.

Mr. J. T. Milton (Lloyd's) wished only to say a very few words upon this matter, and to keep absolutely clear from passing any remarks leading to the advocacy of any one furnace over another. He thought they would

appreciate the reason he did so, but there was one point on which he thought he ought to say a few words, because, as he had read Mr. Morison's paper, he had an implied indictment against Lloyd's as treating his furnace unfairly as compared with the others. He wished to say most emphatically that Lloyd's Committee endeavoured to treat everyone that came before them in any way with perfect fairness. The point alluded to was as to the so-called factor of safety of the different furnaces. He forgot the exact words used in the paper, but they were to the effect that Purves's seemed to have a less factor than the others. That was entirely new to him and had not a basis in real fact. He had had to report upon furnaces to Lloyd's Committee, and had got out a statement, in very nearly the same form as the tables Mr. Morison had put before them, containing the results of all the experiments on furnaces to which he had access. They were all compared on exactly the same basis. Next, in regard to the Morison furnace compared with Fox's furnace, they would see by the experiments that they each had a certain length at the end of the furnace which was not corrugated: it was called the flat, but was not flat, but a plain cylindrical portion. In each of the Fox furnaces made for testing there was a flat at one end of at least 6 inches, the reason being that 6 inches were recognised by the Board of Trade and Lloyd's rules as a reasonable amount of flat to meet the exigencies of design, and out of the six experiments made three collapsed at the 6 inch portions. As he read the result of these experiments, it appeared to him that the 6 inch flats were slightly weaker than the corrugated portion of the Fox furnaces. In the Morison furnaces tested, the flats were made shorter, but even then some of them failed at the flats. Taking the whole of the results into consideration, he thought that the corrugated parts of both furnaces proved slightly stronger than the flat portions, and as the 6 inch flat portion has to be provided for in both cases, the Morison furnace had no advantage over the Fox, and they should be dealt with exactly on an equality. He submitted these views to Lloyd's Committee, and they approved of a similar formula for each of the Fox and Morison furnaces. He desired to say that from the experiments made they had exactly the same measure of justice meted out to them as the Purves furnace, and neither he nor any of Lloyd's Committee would like to see any preference shown so long as they all gave good results. The Purves and Fox had done good work for so many years that it would be difficult to say that either failed to give good satisfaction when properly treated. Mr. Morison had put forward in his paper many points which he (Mr. Milton) could only take as expressions of

opinion, and he could not take them as proved facts. At the same time he thought they ought to be very thankful to Mr. Morison that he had expressed these opinions, and had submitted them to criticism in the bold way he had done. Many of these opinions as to the so-called high tension steel were, he thought, mere opinions based neither on fact or experience. He did not feel himself that he had sufficient experience to criticise them too severely, as they were matters rather for steelmakers than for engineers. He was very pleased, however, to hear what Mr. Gross had to say on the matter, and probably some other steelmakers would say which was right. The whole suitability of steel for furnaces depended upon its ductility. "Definite mechanical movement" exceedingly well expressed one of the many of the points which can only be provided for by ductility of material. If Mr. Morison and other engineers carefully gauged their furnaces under pressure, especially in double-ended boilers, either with single chambers or with separate chambers, they would find out a great deal more of this definite mechanical movement than ever took place from alterations of temperature; the mechanical movement, due to pressure only, was more than some of them had ever dreamt of. He had had this looked into by some of his colleagues, and the results rather startled him. In some boilers which had given trouble there was "definite mechanical movement" in the middle chamber to the extent of $\frac{3}{8}$ths of an inch. There could be nothing like that in the expansion of these parts of the boilers due to temperature. He found at the test pressure, 360 lbs., the horizontal diameter in the middle of the boiler decreased fully half an inch. Now, if all these changes which took place were due to alteration of pressure, it necessarily followed they must use material with the utmost ductility that could be obtained. These motions took place in every boiler of ordinary design, and if from any cause the material of the boiler lost its ductility then these "definite mechanical movements" became of exceedingly great importance, and he had doubt in his mind they were the cause of material, which was not ductile, failing and cracking. He (Mr. Milton) could not say any more than Mr. Gross had said about high tensile steel and low tensile steel. When he spoke of 40 ton tensile steel he should call that high, very high, and should hesitate very long before he should use it in a boiler. It could only have been used in a boiler when it was the best material attainable; but ever since 1877, when steel began to be used for boilers, 26 to 30 tons was considered *mild* steel, it having a very large amount of ductility. He thought time had proved it to be extremely suitable material for boilers. He had yet to learn that steel of from 24 to 26 tons was alone possessed of ductility sufficient for boilermaking. Mr. Gross had been

good enough to tell them in regard to the Admiralty experience—they used exceedingly mild steel for their furnaces—that they had as much trouble with them as anybody else. The steel they used had failed as signally as any other, and, indeed, in one vessel they had a worse record with mild steel under 26 tons than he had ever known with steel from 26 to 30 tons. The steelmakers had the experience and knowledge of the properties of steel, and should enlighten them. He should like to know if there was any real justification for some of the opinions Mr. Morison had expressed on steel? Mr. Morison said mild steel would remain longer ductile than harder steel, meaning 26 to 30 tons, which he (Mr. Milton) said was not hard steel. The example which had been given showed that very mild steel cracked when it lost its ductility, and that it could lose its ductility quite as much as ordinary 26 to 30 ton steel. If they condemned the present 26 to 30 ton steel they would be declaring against the experience of 99 per cent. of the 10,000 furnaces Mr. Gross had been talking about. However suitable the very mild steel was for boilers, the 26 to 30 ton steel had proved itself to be equally suitable, and it must be remembered that it was stronger and therefore did not require such excessive thicknesses. This point was very important because other considerations than strength sometimes limited the thickness which can be used. There was one other point upon which he would really like a little enlightenment in Mr. Morison's paper. He said of corrosion: "It is a question of variation of temperature, resulting in expansion and contraction of the boiler." He said it was for this reason that corrosion was often found at the bar level of furnaces. Now, in one of the first boilers he (Mr. Milton) surveyed, he found an excessive amount of corrosion going on at the firebar level. He was astonished and startled at it; and told the superintendent engineer he could only pass the boiler subject to frequent examination. This he made regularly every six months for several years, and no more corrosion took place. Whether the treatment was altered he did not know; but at any rate the corrosion was stopped. If it had been a question of temperature it must have gone on. Might he ask for one piece of information? Mr. Morison said Lloyd's allowed a greater thickness than $\frac{5}{8}$ths. The thickest he was aware of was $\frac{3}{4}$ inch, and he had hesitated advising the committee to approve of anything more than $\frac{5}{4}$ inch; but if there were any thicker doing good work he should be very glad to know it.

The PRESIDENT said he would like to ask Mr. Milton one question. Did the mechanical movement spoken of take place at the working pressure of 150 or 160 lbs. or at the test pressure of 320 lbs.?

Mr. MILTON was very pleased to be able to answer that. Some of the records given him by his colleagues gave only the movements at the test pressure of 320 lbs; but he had had some experiments recorded by one of his colleagues, giving the movements at the working pressure of 180 lbs. and at the test pressure of 320 lbs. in the same boilers, and in each case the movement was exactly a half at the working pressure, of the amount at the test pressure. These movements were absolutely within the elastic limit, and were directly proportional to the pressure. He had made tests at St. Peter's on boilers of ordinary design, and found the movements $\frac{3}{8}$ inch in the diameter. He might say that the figures he had given were not extreme figures.

Mr. E. G. GEARING said he had not expected to speak upon the paper that night. He would endeavour to approach the subject not directly from the position of a furnace manufacturer. He had had experience with furnaces as a boiler builder, as a marine engineer, and also as a manufacturer. To take the question of tensile of steel, he did not agree with Mr. Gross. He admitted at once he had not his experience, but he could not agree that high tensile steel was proper material from which to make furnaces. Mr. Milton had questioned the reasons that induced Mr. Fox to take to steel of low tensile strain. As some of them were aware, the Fox furnace was first made of iron; and Mr. Fox had told him that he tried to approach Low Moor iron as nearly as possible, and with a certain measure of success. References had been made to the great trouble the Admiralty had experienced with cracked furnaces. He admitted it was perfectly true, the Admiralty had had trouble in that direction, but out of 2,400 Fox furnaces supplied to the British Admiralty two only had a history, and no blame was attributed to the furnace manufacturers. These were fitted into a second-class cruiser, and after being replaced the results of the trials were in every way satisfactory. It was not exactly a question of low tensile steel that applied to these furnaces, but rigidity. Up to the time that furnaces were made of steel below 26 tons tensile the percentage of cracks in Fox's furnaces was very small indeed. He had not the exact figures with him, but no doubt Mr. Morison would give those particulars in his reply. If he (Mr. Morison) had not the figures, he would be happy to supply them. Mr. Gross claimed a great deal for what he called the backbone of his furnace; but he (Mr. Gross) said if they kept their longitudinal stays away from the riveted joints of the tube plate, and again if they kept their combustion chamber stays well back also from the riveted joints they would never have any trouble. He quite agreed with Mr. Gross, but what was that but allowing for longitudinal

elasticity? They might not like it, and say that a boiler should not pant, but undoubtedly it would pant. Some years ago, when conducting a series of forced draught trials for the Admiralty, he, with a view to seeing what really happened, had gone into a boiler as soon after the trials as he possibly could—in some cases with a foot or more of hot ashes in the combustion chambers, and had had to put planks to stand on—and he came to the conclusion that it was elasticity that was wanted. These boilers were stayed with crown or sling stays from the combustion chamber to the shell of the boiler, and the boiler overseer insisted that stay joints should have rose-bitted holes and turned pins fitted. As he had the pull, having to sign the test certificates, he refused to do so, unless he, of course, got his pins fitted. The boilers would not stand as long as the pins were a tight fit, and he came to the conclusion that was the cause of the trouble. He procured some boilermakers from the dockyard, and elongated the holes in the stays $\frac{3}{16}$ inch, and after this was done there was no further trouble in the combustion chambers. Therefore, they must have elasticity or the boiler distorts as Mr. Milton had stated. When one of the boilers referred to was under hydraulic test (they were 17 feet 9 inches long and 9 feet 8 inches mean diameter) he had taken particular care to measure the distortion in it. A straight-edge was fixed on the top of the boiler, and arcs were struck at intervals by a trammel before the pressure was applied. When the pressure reached 130 lbs. the deflection was quite apparent, and at the test load of 220 lbs. the boiler shell over the combustion chamber had deflected at least $\frac{3}{16}$ inch. As the boiler weighed, with its water, 37 tons, he thought it might be caused by the supports being at each end only, and he therefore supported the boiler in the middle, leaving the ends free, but the result was just the same; so he knew boilers moved under test, but not the furnaces as stated by Mr. Milton. If Mr. Milton had looked up the experiments conducted by the Board of Trade for ascertaining the collapsing strength of corrugated and other furnaces (when Lloyd's surveyors were present) he would find the movements were tabulated, under increments of 100 lbs. up to 500 lbs., and then by increments of 50 lbs. up to 900 lbs. At 800 lbs. the distortion was only $\frac{1}{32}$nd of an inch, and there was no permanent set till 850 lbs. was reached.

Mr. Milton—The furnaces experimented with were not attached or fixed in the same way as they were in a boiler.

Mr. Gearing—If Mr. Milton took into consideration the attachment at the tube plate end, and that the tube plate was made strong enough to support the strain, he thought the conditions were similar.

Mr. MILTON—He referred more especially to the distortion or deflection of the plates.

Mr. GEARING—He misunderstood Mr. Milton. He thought he said the furnaces. On the question of ductility he would like to know what was really meant ?

Mr. GROSS—Elongation under tensile strain.

Mr. GEARING thanked Mr. Gross. He could not say that he considered ductility was shown by simple elongation. The experiments he had made had been those of the engineer and not of the chemist, but he was borne out by a very good man, Mr. H. Marion Howe, who had published a most complete work on the metallurgy of steel, and he did not consider elongation alone proved ductility.

Mr. GROSS—One of them.

Mr. GEARING—Well, but still ductility apparently was a very funny thing. In reference to Mr. Gross's remarks as to burning so much more coal per square foot of grate per hour than was done on the Atlantic, he could tell them what he had done at sea, having burnt 14 tons of coal per hour with eighteen men.

The PRESIDENT said he would like to put one more question to Mr. Milton. They had had a good deal of information from cross-examination. If 160 lbs. pressure caused a mechanical movement to a certain extent, and by increasing it to 320 lbs. it was doubled, was 320 lbs. not too high a pressure to put on as a test to the boiler, causing that mechanical movement which was beyond its working pressure ?

Mr. MILTON did not reply.

Mr. G. W. SIVEWRIGHT said he had listened to the discussion with a great deal of interest. He could not agree with Mr. Gross's remarks when he stated there was very little difference in the composition of steel that had to stand tensile tests from 26 to 30 tons, and that there was merely a nominal fractional difference in the elongation. Mr. Gross in making this statement may have been thinking of steel of the most costly and purest make, and where carbon was the important factor to deal with, but this was not the steel they had to work with every day in actual practice. His (Mr. Sivewright's) experience of the use of steel commenced in the year 1880, and he must say that hard steel, more especially for shipbuilding purposes, was not so satisfactory to work as mild steel.

There could be no doubt about it that with the mild steel got in the past about 26 tons tensile, at a cost of something like £10 per ton, they had a material ductile in every sense of the word and really reliable to work with; but since that time the authorities had insisted upon higher tensile steel being used, and concurrent with these requirements they had had a considerable reduction in the price of steel until it had come down in price to something like half the original cost. The steel obtained at this price was not so reliable, and the conclusion he came to was, that steel of a high tensile nature was better able to carry impurities than mild steel, and consequently a cheaper material was made. He thought the whole system of testing steel wanted looking into, and would strongly recommend that extensive cold-bending tests be made with steel in every instance, as he was certain that with tests of this description hard and brittle material would be discovered before it could be used in the works. For the last twelve years he had been building vessels in which the cold flanging of material entered largely into the structure, and if by any means unreliable steel was sent in from the mills the cold flanging most invariably found out the faulty material. These failures were more pronounced when the steel was about 30 tons tensile. Although they had Mr. Gross's statement that mild steel was more likely to be filled with blow-holes than high tensile steel; as it appeared from his (Mr. Sivewright's) own observations that the great trouble with steel castings was the existence of blow-holes, and these as a rule were not made of soft steel. As regards the design of a furnace, he thought it ought to be like any other structure that has to stand strains caused by expansion and contraction, and he considered that the first principle in a design to be aimed at would be one that would give uniform elasticity throughout, so as to allow for longitudinal expansion and contraction, and the very question of backbone (which Mr. Gross quotes) as supposed to be an advantage in a furnace by giving it so much rigidity at intervals, he thought was not desirable. He was not going to advocate any one furnace that night, as he had had to do with all three designs, but with what was called the "backbone" design of furnace he had had some experience. A furnace of this description had cracked in a most unaccountable manner, and after taking it out of the boiler it was put under the hammer to test its ductility, and at the first blow this furnace was split in every direction, which it certainly would not have done if the steel had been of a milder make. The material of this furnace was of such high tensile strength and of such a brittle character that it could not possibly have stood a cold-bending test. If Mr. Gross's opinions as a manufacturer of steel are authoritative, why

should Lloyd's and the Board of Trade give so much preference to high tensile steel when he (Mr. Gross) states there is practically no difference between 26 and 30 tons tensile and so little difference in the elongation? By giving his experience as a shipbuilder and shipowner who had tested steel in every possible way, especially for shipbuilding purposes, it was his opinion that the testing of steel was incomplete unless more exhaustive cold-bending tests were made, these cold-bending tests would certainly reject steel containing phosphorus and other deleterious compounds, which was generally the result of using unsuitable pig iron. He was pleased to see that the expression of opinion of so many of the members was against the use of hard steel, as he, as a shipbuilder, had been objecting to it for shipbuilding purposes for a long time. He thought they ought to be much obliged to Mr. Morison for the very great amount of trouble and time he had spent in getting together all the data contained in his paper. The diagrams were of a very elaborate nature, and many of the experiments so graphically illustrated in the diagrams had cost thousands of pounds to make. He considered that although there may have been differences of opinion expressed as regarded the paper on certain points, yet he was sure of this, that the exhaustive discussion would be of benefit to all parties concerned.

Mr. R. HIRST observed they had had a very lively and lengthy discussion upon the different types of furnaces, and a good deal had also been said regarding the "movement" which took place due to the effects of heating and cooling, but he was of opinion that a number of the accidents and failures which occurred might be traced to the design of the boiler itself, and the form or shape of the furnaces. He thought that the reputation for contracting and yielding claimed for the different types of furnaces was carried a little too far, and they certainly had no definite knowledge upon the subject. Having had some experience in the manufacture of patent furnaces both at Leeds and Sheffield, he was convinced that the general design of the flanges was bad, and paved the way for cracks and failures from the treatment the material had to undergo at the flanging fires to convert them into the shape designed by the engineers. In many cases these flanges had a very small radius, especially at the sides of the furnace, necessitating the smiths using narrow fullers, which had a tendency to nick in the plate at the very point where a great many furnaces had given way. Another source of trouble was the practice of staying the boiler too rigidly in the vicinity of the furnaces; he was of opinion if they would allow a little more breathing space they would obtain a better

result. The fault had been to make flanges with a wide spread, which had a tendency to tighten the tube plate; but he could not see what saving was to be gained by trying to get 20 inches out of 18 inches; the thing gave way when in place, proving that the elastic limit of the steel had been exceeded. He knew one designer of boilers who had had 1,100 furnaces made from one drawing: all these furnaces had short flanges about 5 inches deep, with easy curves at the corners, and not one of them had been known to give any trouble. Instances were known where after a long voyage and the engineers being in a hurry to leave the ship, owing to carelessness in the blowing out of the boilers or cooling down, cracked furnaces had been the result; and it was evident if something was not done to admit of the furnaces standing the extra strain due to such treatment they would have more cracked furnaces in the future. He was of opinion, and he had frequently stated his opinion, that the manufacturer of the furnace was not so much to blame as the designer of the boiler who sought to take too much out of the material. Perhaps there had been instances where steel of a high tensile strength had crept in, but on the part of the furnace manufacturer he felt convinced there had been honesty of purpose, and they had endeavoured to the best of their ability to turn out a good article; but he was afraid that in some cases at least the furnaces had not been subjected to good treatment in the boilerworks. Lately he had seen two which had been returned to the maker, having been badly flanged, and he was obliged to admit that the treatment they had received in the boilerworks was simply disgraceful. The object should be to make a flange quickly and with as few heats as possible, the thickness would then be more uniform and less liable to crack.

Mr. Jas. Patterson said he would like to make a few remarks as a boiler designer and as a builder of boilers. He would take the question of design first, as they had heard of it last. Mr. Hirst had given it as his opinion on that point that what the designer had to do was to keep the furnace flanges short. In his (Mr. Patterson's) opinion what the designer had to do was to keep the flanges long, and what the furnace maker had to do was to find out how best to do this. As boiler builders they had had exceptionally little trouble with furnaces—absolutely no cracks or trouble of that kind; they had had a little trouble with leaky back ends, very little; but where that had occurred the furnaces had short flanges, and never when long flanges were used. With plain furnaces of their own manufacture they never had any difficulty in getting these long flanges, and he refused to believe that the makers of patent furnaces

could not make them equally well, in fact they had had long flanges so often with patent furnaces that he had no doubt the makers could in the future do what they had done in the past. He quite disagreed with Mr. Hirst in his opinion as to keeping these flanges short, but was pleased to be able to agree with him on the question of "breathing room." They had been frequently obliged to put far more stays round the furnaces of boilers than were good for them. The point in the paper which to him seemed of greatest interest was the one as to the quality of steel from which the furnaces were made. He thought the future for any furnace depended more on the quality of the material used in its construction than on any detail of design in corrugations, ribs, or flanges. He did not agree with Mr. Morison that the temperature of a furnace plate of an ordinary marine boiler was anything like 600 degs., at which point, according to diagram No. 21, the elastic limit of the material seems to fall so rapidly. He thought the temperature would be found to be much nearer to that indicated by the experiments mentioned by Mr. Crawford, and, he believed, made by Mr. Blechynden. Therefore he thought they had not reached the limit of thickness in furnace plates which could be used with perfect safety. He might say in reference to Mr. Milton's remark on that point that although they had not used plates $\frac{7}{8}$ inch thick, they had made a number of furnaces whose nominal thickness was over $\frac{3}{4}$ inch, and the actual thickness more than the nominal, and in no case had they given any trouble. But the quality of the material seemed to him to be a point to be well considered, and he must confess he was somewhat disappointed at Mr. Gross's statement of the suitability of steel of 28 tons tensile strength for this purpose. He had hoped that Mr. Gross, as a manufacturer, intimately acquainted with the subject, could have thrown some light upon it which would have removed the doubt on their minds as to the suitability of that material. The material had to stand a great stress, and a great variation of temperature, both in the making of the furnace and in its use afterwards, and he had always been of opinion that the milder the steel the better it would stand those different stresses. The opinion had been arrived at in no scientific manner, and he had no tabulated statistics on the point, but from general observations of the working of steel in the boiler shop he had formed that opinion. They had had boiler plates cracked in process of working them to shape for the boilers—it may be by improper handling in the boiler shop—but at any rate they cracked, and in the majority of cases examined the tensile strength of the plate was 28 tons or over, and he could only recollect a solitary case where the steel was close to 26 tons tensile strength. His

opinion, therefore, derived from general observation, was that the less the tensile strength is above 26 tons the better for furnaces, and he would prefer 26 tons as the maximum limit rather than the minimum as at present. They had not yet had any explanation why the plate of higher tensile strength should be equally good. There was another point on which he was much disappointed. Mr. Morison had produced a diagram purporting to show the factors of safety required by the Board of Trade and Lloyd's for different types of furnaces. According to this diagram these authorities are satisfied with a much lower factor of safety in some cases than in others. Mr. Milton had carefully and fully explained to them that Lloyd's had endeavoured in all cases, including that of the furnaces, to deal impartially with rival proposals. But that was not the point. He (Mr. Patterson) would say for those present, and in particular for Mr. Morison, with whom he was personally intimately acquainted, that it was not intended to impute any intentional unfairness to either of these bodies. But the diagram was there, and if it was correct, and as far as he (Mr. Patterson) was able to analyse and examine it, it was correct, some unfairness existed, however unintentional, and if incorrect, it should be quite an easy matter to show where the error lay, but Mr. Milton had not attempted this, but contented himself with disclaiming all intentional unfairness. He (Mr. Patterson) did not agree with many as to the danger in the use of comparatively thick plates, yet he admitted there was an advantage in thinness, and if one form of furnace could be made thinner than another with the same factor of safety, why not allow them to make it thinner?

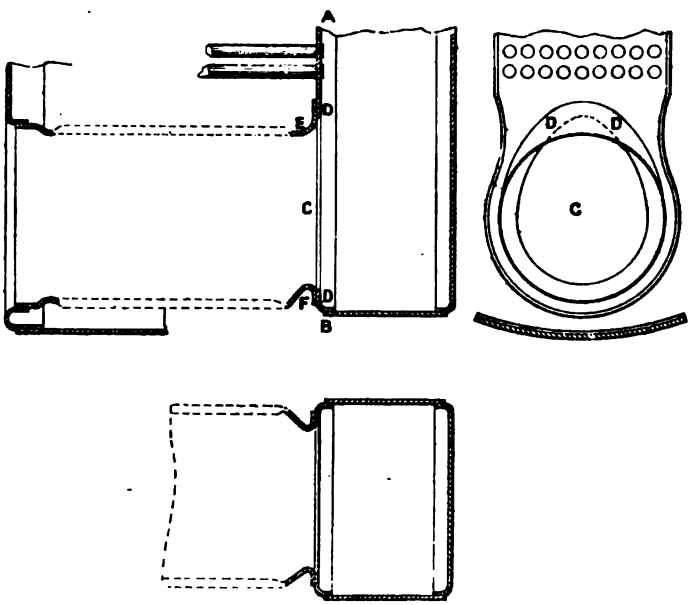
Prof. R. L. Weighton said he just intended to refer to the same matter as Mr. Patterson mentioned. He thought they might leave the merits and demerits of those several corrugated furnaces for time to settle; they could also leave to time (with some assurance that it would be settled) the merits and demerits of high tensile and low tensile steel—time would settle these, though it was important to settle them quickly; but this diagram —factor of safety diagram—time would not settle. That had been troubling him, and although he could not ask his friend, Mr. Milton, for an explanation of the vagaries of this diagram, as he was not responsible for it; still, seeing it had been before the country for some time now, and that all the figures were given, the tests were given and the dates given, it was somewhat strange that no one in the Board of Trade or Lloyd's had gone into the question. He (Prof. Weighton) had looked at it, and although not prepared to say that it might be absolutely correct

in every respect, inasmuch as it was reduced to the common tensile strength of 27 tons, and there might be some objection taken to that reduction, still it was done in regular proportion, and that would not account for these enormous jumps. Was it consistent with the dignity of such departments as the Board of Trade, not to say Lloyd's, to allow it to go as it was without giving some explanation of why it was so? It might have been through inadvertence or want of information, but there it stood—the Purves flue with a lower factor of safety than the Morison flue, and if that was not so they wanted to know from the bodies that had granted it wherein it was wrong. This, too, in justice to the reader of the paper, for really it had taken an immense amount of trouble. He did not think it just that it should be said Mr. Morison had made a mistake in this diagram without it being shown exactly wherein the mistake lay.

Mr. A. E. SHUTE (Leeds Forge) having had some experience in the use of steel in the manufacture of both the Fox and Morison furnaces wished to make a few remarks. Personally, he had a good opinion of the soft steel asked for by the Admiralty for furnaces. It had nothing like so many surface defects as were to be found in steel of a higher tensile strain, such as that used under Board of Trade and Lloyd's rules. It was far easier to work. There was less waste with it, and generally the furnaces, when finished, were a much better job. Mr. Hirst had mentioned one or two facts regarding the durability of furnaces made for a certain firm. He (Mr. Shute) had the making of some 300 or 400 for the firm referred to, and he had not heard anything bad about them yet. Furnaces like the ones in question, having narrow flanges and large radii in the saddle and corners, were easiest to make and gave least trouble afterwards.

Mr. W. G. SPENCE said the paper before them was a very able treatise on boiler furnaces generally. There was one detail, however, which had not been dealt with in the discussion, viz., the methods of attaching furnace ends to combustion chambers, and he would like to elicit some expression of opinion on that point. He had had some experience of the method referred to by Mr. Gross, and had found it an excellent one, but somewhat costly. It, like Mr. Ashlin's, permitted old furnaces to be easily removed and renewed, while it avoided the three-ply corner landings, which so often gave trouble. The arrangement would be at once understood from the sketch on the following page. The tube-plate was ordered

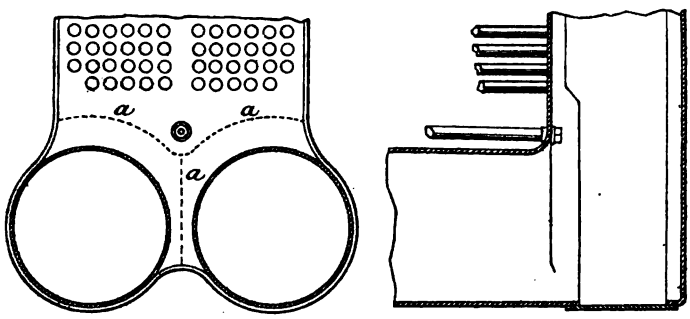
in one piece from A to B, and, after being flanged over, an oval hole C corresponding to furnace mouth was cut out and furnace attached by a single riveted joint D. To remove the furnace it was only necessary to knock out rivets D, draw furnace back and tilt it up. At first sight the somewhat oval section through E F might appear objectionable, but he had never known the least trouble with any of them. Where plain furnaces were adopted, however, he thought nothing equalled welding



the saddle to tube plate right across its whole breadth, as was done by Messrs. George Clark, Limited. This avoided both three-ply corners and riveted joints, and to replace a furnace it could be cut across behind saddle in usual way. Several boilers thus fitted by them had been at sea for about eight months, and so far they had nothing but good accounts of them. It was too soon to prophesy of them, as the only objection to prophesy was the liability of the prophet to err, but altogether they had fitted 96 furnaces in this way, 14 of them being double furnaces opening into one combustion chamber, as shown on the opposite page. He was very glad to see in the paper that Messrs. The Leeds Forge Company had been so successful in their welds. The welds (*a*) were done with special plant.

Mr. HIRST—Were they V or scarf welds?

Mr. SPENCE—They were scarf welds. The steel for the tube plates and furnaces was ordered of special welding quality ; after welding, the whole furnace and tube plate were very carefully annealed in a special furnace. Admitting that even if a weld in this position were to give trouble he thought its flat surface would be more easily dealt with than a riveted joint. He was not going to enter into the question as to the merits of special forms of furnaces, but before concluding he would like to ask if any member had actually experienced serious trouble due to using ordinary plain furnaces, as so far he had found none ? Also as to whether with a given difference of temperature the quantity of water evaporated in a given time above a thick plate was any less than above a thin one between the limits of thickness used for boiler furnaces ?



Mr. GROSS said that as he seemed to have the questionable honour of representing manufacturers of steel—Mr. Gearing would not take that upon himself—he would like to make a few additional remarks. He felt they were all in favour of low tensile strain, and they imagined that 28 tons per square inch was a very high tensile strain. Everything was a matter of comparison. They who were used to boiler work thought 28 tons was a high tensile strain ; they, as steelmakers, for all manner of purposes, thought when they approached 70 tons per square inch, approached a high tensile strain. When they spoke of anything between 26 and 30 tons he thought it would defy any of them, as it did defy the works' chemist, to define even a minute difference between steel at 26 tons and steel at 30 tons. It was only because they were not acquainted, if they would allow him to say so, with relatively high tensile strains, they thought there must be a huge difference between steel of 26 tons and steel of 30 tons strain. The difference of elongation between the two was a mere nominal fraction—there was nothing in it. He had said little to offend any boilermaker present, but if they could believe that by the mere application of the heater to the furnaces they reduced the ordinary elongation of 25 per

cent. in a length of 10 inches to one-half or three-fourths at the most, they would begin to think that the explanation of the shortness of ductility lay much nearer this district than it did the centre of the country. He trusted this was clear—it was all meant for the discussion. There was little absolutely, only the minutest difference between steel at 26 and 30 tons. They might all live to see a very different tensile strain to what they considered high adopted in boilers. It might be considered heresy to say so; but if he could have absolute certainty of the boiler being at rest throughout he would have no hesitation in taking steel of a tensile strain of 35 tons per square inch. He explained that the steel was made in large ingots and samples carefully analysed according to a standard in use for years. Chemically, then, they found no difference between the 26 and 30 tons. If they asked for a shell plate, with a tensile strain of 28 tons per square inch, they, as a matter of fact, must take steel which was as much as 32 tons per square inch. Or if, on the other hand, a plate ⅛ inch thick and 30 tons per square inch tensile strain was wanted, they must adopt absolutely the inverse ratio and use a material which gave them a lower strength; but chemically, and that was the one point he wished to drive home, there was no difference between them, and in elongation the difference was so slight that the failures did not lie there. And what failures were they talking about? They were forgetting the percentage of successes, making everything of the 1 per cent. of failures and nothing of the 99 per cent. of successes. This was the first time he had had the pleasure of speaking to the Institution; if not in harmony with the district, they would excuse him even to going into the elementary part of steelmaking. When they had iron at 20 tons and iron at 22 tons strain the difference was a great thing, but not in steel. The very object of the limits between 26 to 30 tons was because no man living could make a large plate without the latitude of 2 tons per square inch of tensile strain. Chemically, there was no difference: the difference was in the rolling—a very great question in the manufacture of steel.

Mr. MILTON wished to have it made quite clear—did Mr. Gross mean to exclude in his remarks steel under 26 tons strain? Did he really mean that 24 tons steel was just as likely to be injured by the heater as the 28 tons?

Mr. GROSS—Oh, yes; absolutely the same. Mr. Milton, he knew, had made many experiments in that direction, and sooner or later the boiler-makers must face the question thoroughly in that direction.

At this stage the discussion was adjourned, and the meeting dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

NINTH SESSION, 1892–93.

PROCEEDINGS.

FIFTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE, ON MONDAY EVENING, JANUARY 30TH, 1893.

WIGHAM RICHARDSON, ESQ., PAST-PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting, held in Sunderland, on January 13th, 1893, which were approved by the members present, and signed by the Past-President.

THE LATE MR. JOSEPH L. THOMPSON.

Mr. WIGHAM RICHARDSON (Past-President), before beginning the business of the meeting, said he was sure they would all agree with him in an expression of regret that he should find himself in the chair that evening owing to the absence of their respected President (Mr. Robert Thompson, of Sunderland), and owing to the fact that this absence was caused by the death of his father, Mr. Joseph L. Thompson, the head of the firm of Messrs. Joseph L. Thompson & Sons, Sunderland, a firm of very long standing, and of a standing which had made it one of the foremost in that district. He had not known the deceased personally; but he never heard anything of him that was not to his credit. He lived a long, an

arduous, and a laborious life, and turned out a large amount of thoroughly good work. His business would be carried on by his three sons, all of whom during their father's life lived in complete accord and community with him, assisting him to carry on the business. They felt it was a loss to them all. The President's interest in that Institution, however, he was sure, would not be abated, and hoped that by the next meeting he would be with them again.

The discussion on Mr. D. B. Morison's paper on "Marine Boiler Furnaces" was resumed.

A paper "On Apparatus for Determining the Amount of Water Suspended in Steam," by Mr. W. R. Cummins, was read by the SECRETARY.

ADJOURNED DISCUSSION ON MR. D. B. MORISON'S PAPER ON "MARINE BOILER FURNACES."

The following communication was read by the SECRETARY :—

BLECHWALZWERK SCHULZ & KNAUDT,
ACTIEN-GESELLSCHAFT, ESSEN [RUHR],
December 28th, 1892.

D. B. MORISON, Esq., Hartlepool Engine Works, Hartlepool.

DEAR SIR,—In further reply to your favour of the 10th inst., we beg to inform you that we have manufactured corrugated furnaces for the past twelve years, and have turned out about 16,500 of the same, nearly the whole of this number being made of steel plates having a tensile strength of from 23 to 26 tons per square inch.

The manufacture of these flues has proved to be a perfect success, cracking only taking place when plates of greater tensile strength were used.

About 500 flues out of the above bulk were made of hard steel exceeding 26 tons tensile, and the fatal consequences arising from the use of this material have been such as to induce us to refrain entirely from using it any longer. We have even declined orders for corrugated furnaces when specified to be of from 26 to 30 tons tensile, as with our extensive experience we could not see fit to accept them, and we may say, without exaggeration, that the good results and the reputation of our furnaces are mainly due to this policy.

The before-mentioned 500 flues did not present difficulties during the process of manufacture at our works ; also, the boilermakers could finish their jobs easily, no accidents interfering with them, but things changed rapidly when the boilers were set at work. Either sooner or later cracking occurred, and it is a matter of fact that the complaints of our customers relating to the 500 hard flues very far exceeds those relating to the remaining 16,000 furnaces made of low tensile steel. The latter were always found faultless, provided the boilermakers were skilful workmen.

Now, we are of opinion that the other parts of marine boilers, especially fronts, tube plates, etc., are exposed to similar, though less severe, strains to the furnaces themselves, and that it would be better to apply a milder steel even for these parts of the boilers.

This view is generally adopted in this country, therefore land boilers, if not made of wrought iron, are only built of mild steel plates with a tensile strength of from 23 to 26 tons.

The construction of marine boilers, however, is regulated by Lloyd's rules, therefore plates of a tensile strength of from 26 to 30 tons are generally adopted for such purposes, the consequences as regards furnaces being, of course, the same as in your country.

It is now evident that if Lloyd's would break the ice and no longer admit of a reduced thickness for hard plates, the latter would disappear; German Lloyd's and Bureau Veritas would soon follow their example, and even if the Board of Trade should prefer to maintain their firmer views on this subject they could not alone bar the road.

In case the realisation of such a step should be a too radical measure in the eyes of your countrymen they might at least in part advance towards this end, and maintain the high coefficients only for plates really subject to tensile strain, whilst those parts exposed to bending strain should be made of low tensile steel; only cylindrical shells would then profit by the use of plates of from 26 to 30 tons tensile.

We shall be exceedingly pleased to have your opinion with regard to the view we take.

Yours truly,
O. KNAUDT.

The PAST-PRESIDENT said Mr. Milton, who was so well known to them on the Tyne, had asked to be allowed to give some explanation in reference to what was said at the last meeting, and he believed they would be pleased to hear him.

Mr. J. T. MILTON thanked the members for giving him this opportunity of explanation, and desired that he might be permitted to read his statement, which was as follows:—

Prof. Weighton and Mr. Patterson pointedly asked for an explanation of the peculiarity of the diagram shown in Fig. 19, Plate XXXI., which had led them to suppose that Lloyd's Register unduly favoured the Purves furnace by according to it a lower factor of safety than is required with other furnaces.

It was stated at the last meeting that this was not the case, and that Lloyd's Register treated all furnaces with equal fairness so far as the experimental data at their disposal permitted; and the following facts, taken in conjunction with the information given in Mr. Morison's tables, will show the correctness of this statement.

At the outset, it is scarcely necessary to state that our knowledge of the strength of furnaces, or any other structure, must be based upon the results of experiments of some kind; and further, that even with the most simple experiments, apparently duplicate tests do not give identical results. Even the simple tensile test, the simplest of all experiments, will give differences of results both in ultimate tensile strength and in elongation from pieces cut from side by side positions in the same plate. It can only, therefore, be expected that the results of experimental tests of furnaces, when each one is made from a *different* plate, will show somewhat different results.

Mr. Morison's tables show these differences. In the last column but one of each table, from I. to VII. (see pages 132 to 138), the results show that, even making all allowances for slight differences in diameter, thickness, and original strength of material, there are considerable differences in the results of similar tests. For instance, in Table II., in the last six tests there is a difference of 17 per cent. between the best and worst result; in Table III. the difference is 20 per cent.; in Table IV. it is 11 per cent.; in Table V. there is about 70 per cent.; in Table VI. there is 20 per cent.; and in Table VII. there is 4 per cent. Now, each of the experiments in any one table is of the same reliability, and therefore the reasonable way of dealing with the information they give is to take the *mean* of the results.

If diagram, Fig. 19, Plate XXXI., and the corresponding Table VIII., page 139, are examined it will be seen that this has not been done. Commencing at the left, the spots 1 and 2, marked L, each represents two experiments out of the six recorded in Table II. In this table the variation is 17 per cent.; but the two selected are practically the two *best* results. Spots 3 and 4 refer apparently to the first two and the last two of the experiments recorded in Table V. The last two of these are part of a series of six, including differences of results amounting to 70 per cent., and it is to be noted that these two are apparently practically the *worst* of the six.

It should be stated that the experiments in Table V. are not known at Lloyd's Register, so that they can have had no influence in determining the rules. Spot 5 apparently represents two experiments selected

out of the seven recorded in Table VI. Here, again, it is to be noticed that one of these is the very worst of the series. Spot 6 represents the mean of two out of three experiments recorded in Table IV. Spot 7 represents a selection of two out of the five records given in Table III. The remaining spot represents two out of six experiments recorded in Table VII. Even if it were possible to fairly represent the factors of safety required by Lloyd's rules in the manner attempted in Fig. 19, it certainly, in his opinion, was misleading to give selected results instead of *mean* results; or at least, if selected, the basis of selection should be the same in all cases.

Turning next to the factor of safety, Lloyd's rules for such furnaces as are under discussion contain an expression (T—2). The effect of this is seen in the diagram, Fig. 19, Plate XXXI. Furnaces, like all other parts of boilers, are liable to loss of strength through corrosion, and Lloyd's rules have to provide in some measure for this. The result of the expression (T—2) is, that as thin furnaces lose a greater proportion of their strength than thick ones, from a given amount of corrosion, they are originally required to be made stronger. After an amount of corrosion represented by about $\frac{1}{8}$ of an inch, the various thicknesses of furnaces, if proportioned by the rule, will still possess an equal margin of strength. If, for instance, a $\frac{5}{8}$ furnace when new possesses a margin of five times, and a $\frac{3}{8}$ furnace of six times, when each is weakened by say $\frac{1}{8}$ of an inch of corrosion, each will have a margin of four times. It is seen from this that only furnaces of the same thickness can be illustrated by such a figure as that in Fig. 19.

Now, as to the actual figures by which Lloyd's rules were determined for the different classes of furnaces. The experiments were those given by Mr. Morison in the last six tests recorded in Table II, and the whole of those recorded in Tables III., IV., VI., and VII. The exact figures in Lloyd's records are not in all cases precisely as given by Mr. Morison, but in the main they very fairly agree. It will be convenient to commence with the results of Purves's furnace as recorded in Table VI. Of these experiments the first two were discarded because they were made of such thinness as could not be made in practice. (He believed the plates were planed out of thicker ones, as it was impossible to roll them.) The mean of the figures given in column 12 against the five remaining tests is 74,915, and this divided by 1,160, the co-efficient in Lloyd's rules for Purves's furnaces, is 64·6. It may be well to state that the records given by Mr. Morison of the tensile strengths of the steel used in these furnaces

are not in accordance with the information in the possession of Lloyd's, which led them to take 27·2 tons per square inch as the mean strength of the five tests.

Next turn to the six last tests given in Table II., which are the tests on which Lloyd's rules for Fox's furnaces are based. It is noticed at once that the tensile strength of the steel used is 29 tons mean. As this undoubtedly had an effect in making the furnaces stand a higher pressure in order to compare with the previous tests, the results must be reduced in the proportion of 27·2 to 29. Lloyd's rules take the *greatest* diameter as a basis for this type of furnace, and give a co-efficient of 1,259. Mr. Morison, in column 12, has taken the *mean* diameter. If his figures are made to agree with the greatest diameter which is taken in Lloyd's rules, the mean of the column comes to 86,723. This divided by 1,259, and then reduced as above indicated to the proportion of $\frac{27 \cdot 2}{29}$ gives 64·6, the same figures precisely as with Purves's furnace.

The figures in Table III. are not correct as regards the diameters. Mr. Morison has taken as *mean* diameter the *greatest* diameter, as measured by Lloyd's surveyors who witnessed the tests, minus the thickness of plate, whereas the mean diameter is about 2 inches less than the greatest diameter. Calculating the figures which ought to be in column 12, if the greatest diameter were taken, it would give a mean result of 57,851, which divided by 912, the coefficient in Lloyd's rules, gives 63·4, which is only slightly different from the preceding. It should be observed that Lloyd's have *no* record of the strength of steel in this case, neither apparently has Mr. Morison, who merely states assumed 28 tons.

The next furnace to be considered is Holmes's, the results being given in Table IV. The mean of the figures in column 12 gives 60,995, which divided by 945, the coefficient in Lloyd's rules, gives 64·55, which is practically the same as in the Fox and Purves furnace. The mean strength of steel is recorded as 27·2, the same as in the Purves furnace.

This deals with all the furnaces except the Morison. In dealing with this it is necessary to refer to the experiments on Fox's furnace. In each of the six tests on these the usual 6 inches plain portion was left at one end, and four out of the six furnaces failed at these ends, three out of the six did not yield in the corrugation at all. These results show that a 6 inches plain portion is likely to be slightly weaker than the corrugated part. In the Morison furnace there is the same amount of plain portion to be provided for. In the actual tests, however, the plain

portion was only 4½ inches and 5 inches long, and did not therefore so fairly represent actual practice as the Fox tests. Although these plain portions were shorter, two out of the six tests failed at the shorter flats. It could therefore only be considered, in comparing these furnaces with Fox's, that the plain portions of 6 inches length in each being the weakest portion of each, the rules for both forms should be identical.

He was grateful to the Council for permitting this opportunity of explanation, and was sure that all the members of the Institution would feel that it was desirable that no undeserved stigma should be allowed to be attached to the committee of Lloyd's Register, whose reputation for perfect fairness and impartiality is world-wide.

The PAST-PRESIDENT thought they would consider it satisfactory that Mr. Milton had had an opportunity of explaining his views so exhaustively.

Mr. C. GEDDES observed that so much had been said on the paper under discussion that it did not appear to him as if there was very much left for anybody else to say. There was, however, one point that had been left out in the cold, which had a direct bearing on the question of high and low tensile steel as applied to furnace manufacture. Theoretically speaking, furnaces should *not* alter their form, collapse, or become distorted; but, as most of them were aware, they did so, and some of them knew it very considerably to their cost. It was not necessary, perhaps, to go into the causes of these failures, because they were many and varied; it was sufficient that they did occur, and when they happened they had to be dealt with. In his position for some years as technical representative of the Leeds Forge Company, and later still, in his private practice as an engineer and expert on boiler furnaces, he had been frequently called in to advise, and not unfrequently to supervise, the work of setting back distorted furnaces, and never, until a comparatively recent date, had he had the slightest hesitation to apply fire to facilitate the work, and only on one occasion had he known of injury or accident to arise from it; but that instance was so remarkable that it tinged and coloured his views and ideas on the subject, and in no small measure altered his practice. A plain furnace in an Atlantic cattle boat had pocketed in the crown, about its mid length, to the depth of 1¾ inches, the pocket measuring otherwise some 24 inches long by 12 inches wide. Before beginning to set it up, he talked the matter over with the consulting engineer of the company, and decided to proceed, as he had often enough in similar cases, by building

a wood fire on the upper and under side of the plate until it was of a blood-red heat, and then with a pair of power jacks had no difficulty in putting the distortion back to its original position. When finished, the job seemed a good one, and, metaphorically speaking, they patted each other on the back over it. However, to make assurance doubly sure, he went into the furnace to have a look and was not a little amazed to see a crack 6 inches long, in a longitudinal direction, clean through the plate. The most singular thing was that this crack was 6 or 7 inches away from the point dealt with. He was a good deal puzzled, and found it very difficult to account satisfactorily for it; and came to the conclusion that eight out of every ten men would, in the circumstances, that it was due to defective or inferior material. He made it his business to enquire into the history of the plates. He had not access to the records of the firm that made them; but found the plates of excellent quality, but of very high tensile value, 28 to 30 tons, and they were $\frac{1}{2}$ inch or $\frac{9}{16}$ths in thickness. He was firmly persuaded in his own mind that this crack was due to the disturbance of the molecules of the steel between wind and water, as it were, in the regions between heat and cold, and that the crack would not have occurred had the plate been of a milder quality. At least, he had not known of a case, nor had he ever heard of one, with milder steel. Since that occurrence he had been careful to enquire into the age of the furnace before attempting to treat it with heat, because it was only in the last three or four years that high tensile steel had come to be used in furnaces, and it could not be too carefully borne in mind, whatever the tensile value might be of the material when it was put into the boiler, it was very much increased by coming into constant contact with the fierce heat of the fire, and impossible to tell what it might be after running some years. He would like to mention another case of more recent date. A corrugated furnace of a celebrated liner had, from a good and sufficient cause, collapsed and come down to the extent of $2\frac{3}{4}$ inches. In this case the engineer in charge had, he believed, the assistance of a very experienced and capable surveyor to Lloyd's Register, not the only one they had in Liverpool, he was pleased to say, and this gentleman, knowing that the furnace had been supplied at a comparatively recent date, concluded very justly that they were likely to be of high tensile value, and to apply fire would be to run a considerable risk, and therefore decided to do it cold, which was done, and so satisfactorily, that when the furnace was afterwards gauged it was found to be within a quarter of an inch of truly cylindrical. But it required the full power

of two 100 ton jacks to do it; and these could not be found at every port a steamship might arrive at. If, however, furnaces had been of a milder material heat might have been applied without risk, and the same work could have been accomplished with a pair 15 or 20 ton jacks, which he ventured to say could have been found at any port. He put this before them as an additional reason why mild steel should be used in place of high steel where the plate was likely to be exposed to fierce heat. At their last meeting in Sunderland one of the speakers, in his defence of high tensile steel, suggested that Mr. Fox, of the Leeds Forge Company, must have considerable confidence in the high tensile steel, and be satisfied as to its suitability for the purposes of furnace manufacture, otherwise he would not have gone over to it and left the milder steel. Now, as this suggestion was capable of misconstruction, he (Mr. Geddes) would like to mention that he had on frequent occasions to discuss this subject with Mr. Fox, and was in a position to say Mr. Fox was not, and never had been, an advocate for high tensile steel, and would never have adopted it had he not been forced to follow the lead that was set him. He was obliged, for commercial reasons, to get on level terms with a competitive firm that had already taken the initiative, and by doing so had got a rung in the ladder above him. He (Mr. Geddes) had a shrewd suspicion that it was to get that rung higher that they took that step, and, having got it, were able to dance to a very pleasant tune, but the engineers and the shipowners had not unfrequently to pay the fiddler. Mr Gross took some pains to prove that the difference between 24 to 26 ton steel and 28 to 30 ton steel was infinitesimally small. Chemically speaking, he (Mr. Geddes) was not prepared to dispute the point; mechanically speaking, he meant where the plate had to be heated or treated or punished severely, it was well within his experience that the difference was very considerable; and commercially speaking, he thought it fair criticism to say, that if any one of them could pocket the difference the departure from low to high tensile steel had made to the firms of furnace manufacturers who first took that departure they should consider themselves very well off whatever the results might be to the users.

Mr. J. F. Walliker remarked that he had made some notes before the beginning of the last meeting, but he feared that many of them might be out of date now. In the first place, Mr. Morison on page 112 (*b*) had told them that "the material in the furnaces should be so disposed as to give the greatest resistance to collapse without undue longitudinal

rigidity." This appeared on the face of it a strong commendation of furnaces of the ringed type; but as they had had comparatively no trouble with plain furnaces from their form, which was rigidity itself, it followed that the only breathing required was in allowing room *round* the furnace, and Mr. Morison's note as to the stays surrounding furnaces being made a slack fit and with a big radius to plate commended itself to all. On the same page there was a note that furnaces should be of such formation that they could be easily scaled, etc. This he (Mr. Walliker) thought should be looked after more than it was, as, however good the formation, it could be quite spoiled by inaccessibility, some engineers thinking they had done all that was required when they had put some peepholes over the tops of the furnaces. If, however, instead of this they would take away the bottom row of tubes, generally full of soot, and thus allow more room for men, and not boys, to clean, the boilers generally, and the furnaces in particular, would all have a chance of a longer life. Small doors were an incentive to laziness. Mr. Morison also stated that many engineers used plain furnaces up to $\frac{3}{4}$ inch thick, and in the next line he said they were of small diameter; a plain furnace $\frac{3}{4}$ inch thick could be over 41 inches diameter for 160 lbs. He did not think they could say that a furnace was small at 3 feet 5 inches diameter. A little further on it was stated that excessive corrosion was often found in plain furnaces at the grate level, but he could assure Mr. Morison that this fault was by no means confined to these: it was found in every type, and in his (Mr. Walliker's) opinion was often due to want of care and experience of those in charge. In the improved furnaces pitting was heaviest at the end of the corrugations, the inside part being comparatively clean. Mr. Morison gave Lloyd's limiting rule, but had omitted the 10 per cent. additions for furnaces over $\frac{9}{16}$ths thick. He (Mr. Walliker) thought, too, although it was stated otherwise, that cracks in improved furnaces were not quite unknown before 1890, the date at which the introduction of the higher tensile strength was fixed, and by referring to any experienced engineer many instances could be brought forward where cracks in improved furnaces had given an immense lot of trouble and annoyance before that time. Here he might add the testimony of the Admiralty failures, which had been already alluded to, and which he wished to emphasize, because the material used was of a low tensile strength. He thought they were indebted to Mr. Milton for pointing out the internal stresses under the ordinary conditions of work, and to which in his (Mr. Walliker's opinion more than to material they had to look for the reasons of some of their failures. Only last week he examined two single-ended boilers of four

furnaces each, the two centre ones with common combustion chambers, and found the furnaces (which were of the plain type), all cracked at the flange, and the pieces cut out and patched, and evidently giving no trouble. Mr. Fothergill was persuaded that furnaces should not crack if they collapsed as low as the bars. He had seen furnaces that collapsed lower than this; indeed, a stout man could not get underneath, and this without the slightest signs of fracture. It might be worth noting that many firms enjoyed an entire immunity from furnace and other similar failures. He should like to ask Mr. Fothergill whether the furnaces he showed examples of as cracking were worked under any system of forced draught, as he thought they should know all the circumstances in each case before giving an opinion?

Mr. FOTHERGILL—Yes.

Mr. WALLIKER—One gentleman, representing the steelmakers, at the last meeting spoke chiefly about high tensile steel. He (Mr. Walliker) did not think any misstatement had been made; the matter was pretty familiar to most of them who had had experience in testing steel, and although Mr. Geddes had said that if they put a lot of work upon steel it altered the use it could be put to, he could not say he agreed with him. He found that a moderate amount of work on steel absolutely improved it. Mr. Gross told them that 26 and 30 ton steel were chemically identical, and he would like to amplify this by a little example. If they took an ingot of steel and cut it into two pieces—one-half of it, if rolled to, say, 1 inch thick, would break under the limit (*i.e.*, 26 tons), while the other half, if rolled out to ½ inch thick, would break at, say, 28 to 30 tons, which their friends called a high tensile steel, although the two pieces were off the same ingot, and were equally satisfactory for ductility; it seemed to him a decided misnomer to call one piece high tensile and the other low. His conclusions were:—(1) Steel from 26 to 30 tons tensile strain had for many years given the utmost satisfaction in plain and improved furnaces; (2) steel under these strengths had failed in the same degree as the higher tensile material; (3) that to design, lessons learned from careful experiments—such as indicated by Mr. Milton—ample breathing space, and proper treatment in manufacture would in the future as in the past give them the best immunity from accidents.

The PAST-PRESIDENT asked if steel, said to be of a certain tensile strength, was on the inch or half-inch thickness?

Mr. MILTON said it was at the thickness the plate was used.

MR. MORISON'S REPLY.

Mr. D. B. Morison, in reply to the discussion, said the value of an engineering paper of a practical nature depended to a great extent on the discussion, and he took the earliest opportunity of thanking the various gentlemen who had given their views on the very important subject of marine boiler furnaces. At no period, in the history of marine engineering, had furnace accidents been so numerous as of late, and he felt confident that the definite expressions of opinion from the many eminent engineers who had taken part in the discussion would result in an immediate and permanent improvement in the material of which furnaces were made. It had been remarked, rather ungenerously, that the paper was written to advocate a certain design of furnace, but such was not the case, as he did his utmost to give each design equal consideration, and the descriptive matter relating to each furnace was obtained from and submitted to the various firms before being included in the paper. He was neither a steelmaker nor a furnace manufacturer, and claimed that the paper was written from the standpoint of a marine engineer. He did not propose, in his reply, to dwell on the merits or demerits of any particular furnace; his opinions were definitely expressed in his paper, and from what had been said, he felt there was no cause to alter those opinions; he therefore left the question of the best form of furnace to be settled by practical experience in the future.

He was glad to hear Mr. Alexander Taylor so severely condemn the use of steel, exceeding 26 tons tensile, for furnaces, as he told them that this unsuitable material had caused untold annoyance and expense to all concerned, and from the manner in which he expressed his opinion, he (Mr. Morison) thought they might infer that he also had been one of the many victims who had followed the rapid strides that furnace manufacturers had lately induced them to make. Mr. Taylor disputed the accuracy of his statement, that the greatest thickness allowed by the Board of Trade for furnaces was $\frac{5}{8}$ths of an inch. His authority was the Board of Trade rules. He had made certain enquiries, however, and found that in some cases furnaces had been passed $\frac{1}{32}$ inch above the regulation limit, but he strongly maintained that if any deviation was made from the existing rules, all engineers should be acquainted with the alteration, so that each had an equal chance of sharing any advantage that might result. He quite agreed that shipowners' and shipbuilders' experience of patent furnaces within the last few years had been unsatisfactory. He would go further, and say that many furnaces at present in

use that had been made of very hard steel would crack eventually, more especially if they were in boilers having great variations in temperature, as in the case of forced draught. Mr. Taylor seemed agreeably surprised that he (Mr. Morison) was of the opinion that the pockets in the Fox furnaces were not effective grate area, thus proving the correctness of his claim that the paper was not from a furnace manufacturer's point of view, but from that of a practical marine engineer. He also told them that for a given internal diameter of furnace a boiler with plain furnaces required to be less in diameter than a boiler with corrugated or ribbed furnaces. This was, of course, correct; but it should be remembered that furnace design was the result of compromise, and the best furnace was, in his opinion, the one which contained the greater number of apparent requirements enumerated on page 112 of his paper. If plain furnaces are made under Board of Trade survey from the steel Mr. Taylor and the majority of engineers throughout the world so strongly advocate, viz., from 23 to 26 tons tensile, the greatest internal diameters would be: for 160 lbs. boiler pressure 28·04 inches; for 180 lbs. 24·79 inches; and for 200 lbs. 22·18 inches. If made of high tensile, viz., from 26 to 30 tons, the internal diameters for the same pressures would be 30·97 inches, 27·39 inches, and 24·53 inches respectively. Lloyd's survey allows of a maximum thickness of $\frac{3}{4}$ inch, with a margin of $\frac{1}{32}$ inch for rolling; but should the plate exceed $\frac{25}{32}$ inch in any part it is rejected, and to show how rigidly the rule is enforced a whole set of plain furnace plates were recently condemned because in some parts the thickness exceeded the limit of $\frac{25}{32}$ inch by from $\frac{1}{64}$ inch to $\frac{1}{32}$ inch. If therefore plain furnaces are made for Lloyd's survey from steel of from 23 to 26 tons tensile, the internal diameters for pressure of 160, 180, and 200 lbs. would be 36·00 inches, 31·83 inches, and 28·5 inches; and if made from 26 to 30 ton steel, the diameters would be 39·75 inches, 35·16 inches, and 31·5 inches respectively. This has a most important bearing on the future of plain furnaces, as unless made of the material which Mr. Taylor said had caused untold annoyance and expense, the maximum internal diameter with 180 lbs. for the Board of Trade survey was 24·79 inches, and for Lloyd's 31·83 inches. The diagrams A and B (Plate XXXVIII.) showed the values allowed by the Board of Trade and Lloyd's for steel of varying tensiles for corrugated furnaces, the range of 4 tons being required by the steelmakers. A method sometimes adopted with plain furnaces, in order to get the largest diameter of furnace, with the lowest limit of the high tensile, was to specify the furnace plates with a 1 ton range, viz., from 26 to 27 tons; and whilst Lloyd's would pass a furnace if made of

this material, 35·16 inches internal diameter and 180 lbs. pressure, yet, for one ton less tensile they would require the diameter reduced to 31·83 inches. This was an illustration of driving the proverbial horse and cart through the rules; but it was, he considered, a dangerous course, as the factor was apparently based on steel of 28 tons, and therefore furnaces below the 27 tons would have a less factor than Lloyd's deemed it desirable to allow. The more serious phase of this expedient was, however, the narrow limit of 1 ton for the steelworkers to work to, as they should have at least 3 tons range. In the case cited, viz., limiting the range from 26 to 27 tons, the makers would take care that they did not get below 26 tons, or the plate would be rejected; so if it happened to be above 27 tons, it would be possible to anneal it down to the desired tensile, and he maintained that any plate treated in this way was not improved in quality; as although annealing for the adjustment of internal stresses was to be advocated, further annealing for the purpose of bringing down the tensile should be condemned. Let them face the matter by making up their minds to give the steelmakers a reasonable range of four tons, and settle whether the high tensile or the low tensile was the more suitable. An instance was quoted where £500 was saved in the price of two boilers on account of alteration in design of furnaces. There had been a recent accident, of which many of them were aware, in which ten times £500 would not cover the cost resulting from a failure of furnaces. The furnace is unquestionably the most important detail of a boiler, as from 50 to 60 per cent. of the total steam generated in a boiler was generated from the furnaces alone; this was proved by some very careful experiments made at the works of the Leeds Forge Co. lately by the Assistant Professor of Naval Architecture of the Glasgow University. His remarks as to a corrosion at the firebar level seemed to have been misunderstood, as what was meant was that under exactly similar conditions it was his opinion that if corrosion did occur it would be more severe in a furnace of a rigid design, such as a plain furnace, than in an elastic design, such as a corrugated furnace; and also that variations of temperature had a bearing on such corrosion. An engineer of great practical experience in giving his opinion on the matter said—"It seems to me that a furnace that has longitudinal elasticity will move mechanically under the strain due to the difference of temperature above and below the firebars, and therefore the racking strain on the material is much less than in a rigid furnace, as the latter not being able to move in itself, the metal composing it is more likely to undergo molecular change when subjected to the same treatment, and that being so there is no doubt that the corro-

sion complained of will be more excessive in rigid furnaces than those having elasticity of design."

Dr. Kirk's diagram, which was an exact reproduction of that illustrated in *Engineering*, had also been somewhat misunderstood; what it illustrated was the fact that the thicker the plate the greater the temperature. They were the nearest experiments that he could find relating to the question, and although they had not a direct bearing on the temperature of furnace plates, they showed that the temperature of such plates increased with their thickness, and when they considered that with 180 lbs. steam the temperature of the water was 380 degs., the temperature of the furnace plate on the fire side must of necessity be much greater, and therefore be dangerously near the brittle temperature of steel, especially if the furnaces were made of high tensile. They would, he was sure, agree with Mr. Rolland that furnaces would not collapse unless conditions in actual working contributed to it, and also that the factor of safety of a furnace when in use was less than the apparent factor of safety resulting from the cold water test. It was his opinion, however, that the cold water test was the natural and correct basis for determining resistance to collapse, and that the furnace showing the highest collapsing coefficient would be able to withstand the effects of a heavier accumulation of deposit than the furnace giving a lower collapsing coefficient. It was not his intention in any way to criticise the *amount* of the factors of safety allowed by the Board of Trade and Lloyd's for furnaces generally. His contention was that experiments had been carried out involving enormous expense and with the greatest accuracy, therefore equal consideration should be extended to all by those responsible for the control of furnace manufacture, especially as variations in the factors of safety were not desirable. Mr. Rolland's views with regard to the pockets in a Fox furnace coincided entirely with his own, but experience had amply proved, after a careful observation of the suspension furnaces in use at sea, that the accumulation of scale was not unequal, and compared favourably with furnaces of the ribbed or any other design. This was a question, however, which experience was quickly proving. Mr. Rolland's opinion with regard to high tensile steel were exceedingly valuable, as they represented the results of personal experience, and were, no doubt, the reflections of the opinions of the many eminent engineers in his country. Mr. Rolland asked if the high tensile steel had resulted from commercial competition in furnace manufacture. His reply was most distinctly in the affirmative. Personally, he had nothing whatever to do with determining the

tensile of the suspension test flues—this was regulated by the Board of Trade. What he endeavoured to show by the results of the suspension tests was not that a high factor of safety could be obtained with steel of high tensile, but rather that it was possible to obtain great strength to resist collapse in furnaces of any tensile by a judicious disposition of material. With regard to the diameter of the test flues, one was lately collapsed at the Leeds Forge, 42 inches diameter, and the collapsing coefficient corresponded to those in the tables.

The best thanks of the Institution were due to Mr. Blechynden for the results of his valuable experiments, as these, together with those of Dr. Kirk, would enable them to approximate with a fair degree of accuracy the probable temperature of a clean furnace plate. In doing this, however, it must be remembered that a very thin layer of deposit had often a very appreciable effect, and many of them remembered the interesting experiments made by Professor Lewis, in which he burnt a hole with the aid of a blowpipe through a small iron pot filled with water and having a layer of oily deposit $\frac{1}{32}$ inch in thickness on the water side, whilst another similar pot, with no deposit, was entirely unaffected. As previously explained, his only object was to show that the temperature of a furnace plate approachod the temperature of greatest brittleness in steel, and that this brittleness was intensified by the use of high tensile steel.*

He differed entirely with Mr. Crawford that the internal stresses of a furnace were more complicated with equal thickness and elacticity of design than in unequal thickness and rigidity of design, as his opinion was that equal thickness and elasticity of design was essential to success. He agreed with him, however, with regard to the object of the tables of strength, as they were compiled to show the relative collapsing strengths

* Since replying to his paper Mr. Morison has made some experiments on the temperature of furnace plates with a vessel 18 inches diameter placed over a specially made furnace, the temperature of which was about 2,000 degs. Fah. The bottom of the vessel was a steel plate $\frac{3}{4}$ inch thick, and the temperature of the plate $\frac{1}{4}$ inch from the fire side was 290 degs. with a clean plate and 400 degs. with $\frac{1}{64}$ inch clean hard scale; this scale was then painted over with a coating of cylinder oil, and the scale having increased to a thickness of $\frac{1}{32}$ inch the temperature rose to 650 degs. These results have been confirmed in a paper by A. J. Durston, Esq., Engineer-in-Chief H.M. Navy, read before the Institution of Naval Architects. In an open vessel having a bottom $\frac{1}{4}$ inch thick, and placed over a furnace having a temperature of 2,200 degs., the temperature of the fire side of the plate was 280 degs. and with $\frac{1}{16}$ inch of greasy scale this was increased to 550 degs. In another experiment with a closed vessel $\frac{3}{8}$ inch thick and 110 lbs. steam pressure, the temperature on the fire side, with clean surfaces and clean water, was 430 degs.; with $\frac{1}{16}$ inch of greasy deposit 550 degs., and with using more grease the temperature rose to 617 degs.

of the various designs. The manufacture of each set of the Purves's test flues was no doubt carried out with at least the same degree of care as was exercised in the manufacture of the furnaces they had all been using, consequently they represented results of actual practice. Mr. Crawford said that it did not necessarily follow that the thinner a Purves's flue the better the collapsing co-efficient, but whatever opinion Mr. Crawford might hold the fact still remained. Had Mr. Crawford favoured the Institution with his presence, instead of sending a written communication, his challenge to him that he could not support his statement as to the ripping of a Purves's flue would not have been made, as he would have seen on the table two specimens of such an accident. He could not but dispute the accuracy of the statement that Messrs. John Brown & Co. absolutely denied any knowledge of the cracking at the base of a rib of a Purves's flue, as he knew such a statement to be incorrect, and although only two cases had been brought forward during the discussion many flues had failed in the same manner; but it was never his intention to refer to them, as what they wanted was not a reflection of the past, but a protection for the future. This circumferential ripping in the middle of a body of a furnace had never occurred in a corrugated design, and it would seem that the concentration of movement at the base of the ribs in a Purves's furnace had a direct bearing on such accidents. Reference had been made to the failure of furnaces in H.M.S. "Sybille," which he would deal with later. Mr. Crawford referred to an accident to the "Hecla." Mr. Fothergill, the superintendent of the company, told him this was wrong, and that it was probably the "Etna" which was meant, as in that steamer three Fox furnaces were originally fitted, and these collapsed through excess of scale. The centre furnace was so severely damaged that it had to be cut out, and was replaced by a Purves, the wing furnaces being set up. Later on, the boiler again became so dirty that the original Fox furnaces, which had been set up, came down again, as also did the new Purves's furnace. He failed to see, therefore, what this taught them, except that any furnace would collapse if sufficient scale was allowed to accumulate on it, and that it was necessary for success to keep boilers clean. Another example lately occurred in the same company. The boilers were fitted with Purves's furnaces, one of which cracked in seventeen different places and had to be removed, and replaced with a suspension furnace of low tensile steel. But it was a thankless task Mr. Crawford had undertaken—viz., to prove that certain designs of furnaces should not crack, because they all knew they did crack, and what they wanted to find out was *why* they cracked and the remedy.

He was confident that every member of that Institution was pleased to see Mr. Gross, as he had made himself a general favourite amongst marine engineers by the great kindness and attention he had always shown them. It was with some hesitation, therefore, that he was compelled, in the interest of the subject under discussion, to disagree with Mr. Gross, and the only explanation he could give of the mistakes he had made was that he could only have read his paper cursorily. In the first place Mr. Gross said it was allowed in his paper that the Purves's furnace was as strong as a corrugated and practically even as strong as the Morison furnace—this was incorrect, and he referred Mr. Gross to the results given in the tables, the accuracy of which cannot be disputed, as the Morison tests for example were made under the direct supervision of the highest authorities in the kingdom, if not the world, viz.: the Board of Trade, the Admiralty, Lloyd's Registry, and the Bureau Veritas. No one could of course blame Messrs. John Brown & Co. when they commenced business as flue makers to adopt the quality of materials prescribed for furnaces by the various surveys, but with the ample practical evidence now obtained it was the general opinion that such material was not the most suitable for the purpose. Mr. Gross said that the Purves furnace had actually nearly as much longitudinal rigidity as its grandfather the plain furnace, and was not ashamed of it. Well, if the furnaces Mr. Fothergill had sent samples of were not ashamed of themselves they certainly ought to be. The quality of the material in the furnaces of H.M.S. "Sybille" was beyond reproach, and in the replaced furnaces especially, the greatest possible skill was brought to bear on their manufacture, and yet some cracked a second time. Now, the question was, why did they crack? It was obviously not due to material, and therefore apparently resulted from rigidity. Mr. Gross facetiously remarked that "of course no furnace ever required repairs;" this was unfortunately incorrect, and he was sure the furnace users would agree with him that lately especially, far too many had required repairs, and he considered it a disgrace to marine engineering that it was possible for a man to go into the furnaces of a boiler and with a few blows from a comparatively light hammer crack them in all directions. Surely something must be wrong, and very seriously wrong, in fact they could not gauge the grave results which might follow if accidents happened in action similar to that which happened in H.M.S. "Sybille" when lying quietly in harbour. The most extraordinary statement which Mr. Gross made, however, was the following:—"If high tensile strength is such an objectionable feature in a Purves's furnace as was represented in the paper, why was the average tensile

strain of the Morison experimental flues the highest of all, and the formula obtained on this?" and then he goes on to say, "but all these are minor matters." Now, they were not minor matters, but matters of the greatest importance to all users of furnaces, and as a matter of fact the average tensile of the Morison experimental flues was practically the same as the Purves's 1886 and 1887 experiments —was 1 ton lower than the Board of Trade 1889 Purves's experiments, and was practically 2 tons lower than the Fox 1891 experiments, and yet Mr. Gross said that the Morison test furnaces were made of the hardest steel of all. His reason for emphasizing this so much was because he noticed that Mr. Gross's remarks were fully reported in the *Lloyd's Shipping Gazette*, and misstatements of facts such as these could not but have an unfortunate general effect. Mr. Gross stated that having counted all the failures in the Purves's flue he found they were less than 1 per cent. of the whole they had manufactured up to date. It would have been more correct had Mr. Gross said that he had counted up all the failures of which he *was aware*, as he (Mr. Morison) was convinced that his estimate was very much too low. It was impossible to get authentic information regarding cracked furnaces, as men who had had accidents did not volunteer the information, as they naturally felt there was some reflection in the matter. Mr. Gross asked if the percentage of the corrugated was any less. Prior to the use of high tensile steel it was very much less, as the figures Mr. Gearing gave showed that only two furnaces supplied to the British Admiralty out of 2,400 had cracked —this record was certainly much less, being not 1 in every 100 over a period of four years, but 1 in every 1,200 over a period of twelve years.

Mr. Gross then went on to ask—"Has the Morison furnace, young as it is, been free from mishaps entirely?" As far as he knew personally, and he had also made enquiries from the Leeds Forge Company, no complaints whatever had been made with regard to those at present in use, and they were fitted in the British Navy, Atlantic liners, in mail steamers, and in cargo boats with both natural and forced draught; but we should have been very much better pleased had the whole of these furnaces been made of steel not exceeding 26 tons, although, of course, this was beyond his control. In his opinion longitudinal elasticity would never be proved to be of disadvantage in furnaces as Mr. Gross implied, and recent events should be sufficient to convince the most sceptical. Mr. Gross asked where stands the argument about elasticity of design if the Purves's furnaces cracked because of their stiffness endwise and the

Fox furnace in spite of their supposed elasticity. Before dealing with this argument it was necessary to distinguish cracking and ripping. Cracking should mean the small cracks generally about ½ inch to 1 inch in length and taking place in the bosom of the Fox corrugation, and at the base of the rib in a Purves's furnace generally a few inches above the fire bar level in both cases. This cracking was due to overheating of material caused by an excess of deposit. The most serious form of cracking, however, was ripping, and was the sudden explosion of a furnace similar to two cases cited by Mr. Fothergill, and the many cases in H.M.S. "Sybille." Again, taking the experience of Herr Von Knaudt, it could not be disputed that he had proved it to be a fact that if furnaces had longitudinal elasticity of design, and were made of mild steel, they would not rip, therefore Mr. Gross's argument could not hold in view of an experience extending over twelve years, or nearly three times as long as Mr. Gross had been intimately acquainted with furnaces, and with numbers exceeding nearly 60 per cent. those manufactured by Mr. Gross's firm, besides this the Leeds Forge Company, after making 30,000 furnaces, said—"Use mild steel if you want the greatest success." Mr. Gross remarked that it was undesirable to have furnace failures. Marine engineers and shipowners said it was not only undesirable but unnecessary and ruinous. It would be little consolation to inform a shipowner, whose boat was delayed with cracked or ripped furnaces, that they really should not have cracked, because the chemical difference between high and low tensile steel was after all infinitely small. What boiler builders and shipowners wanted was better material in furnaces whether they were corrugated, ribbed, plain, or any other kind. Mr. Gross's experience was that these failures practically never occurred in a single-ended boiler, yet it was a curious fact that both specimens which they had before them were from single-ended boilers. Mr. Gross said the solution of the question of avoiding trouble from cracked furnaces did not lie in the direction of low tensile; this, perhaps, explained the fact which he had often noticed, that ribbed furnaces were often as high as 29 to 30 tons. There was, however, another reason, as the higher the tensile steel used for test furnaces the greater was the collapsing coefficient, and it was worthy of note that the first tests with the Purves's flue were with 26·9 ton steel, the second series with 27·28 ton steel, and the third series was 28·25 tons. He understood, in fact, the increase of tensile was one of the reasons why each series of tests gave a higher collapsing coefficient. This desire on Mr. Gross's part to use higher and still higher tensile with a view of getting higher and still higher coefficients

was after all only natural, as Mr. Gross said there was really no chemical difference, and why not use the hardest steel the authorities would allow, but it was a striking fact that with the exception of the Engineer-in-Chief of Lloyd's Registry, who did not see why high tensile should not do as well as low tensile, no one who had spoken on the paper agreed with Mr. Gross as to the suitability of the high tensile steel they had lately been getting for furnace manufacture. The Leeds Forge Company after an experience of fourteen years and a manufacture of 30,000 furnaces condemned it. Messrs. Schulz & Knaudt, of Essen, with an experience of twelve years in the manufacture of 16,500 furnaces, condemned it; American furnace makers condemned it; the British Admiralty and the leading Admiralties of the world condemned it, and yet Mr Gross and Mr. Milton considered it quite as suitable for furnace manufacture as the milder steel. All engineers would agree that the following remark of Mr. Fothergill's was one of the most valuable in the whole discussion, viz.:—"There are excuses for distortion of furnaces, but certainly none for cracking, and the material should be of such a quality that the crown might come down even to the bars and yet not crack." Now, this was exactly the material that boiler builders wanted for furnaces. They did not care what the chemical constituents of the steel were as long as it fulfilled the practical requirements in the working of a boiler at sea. All of them recognised in Mr. Fothergill a marine engineer of great practical experience, and with reference to hard material he said—"He most emphatically objected to the use of thin plates if their strength depended on the use of high tensile material;" and he thought he was correct in saying that Mr. Fothergill would not now, on any condition whatever, accept furnaces of any design unless they were made of steel between 23 and 26 tons tensile. The specimens of ripped furnaces, which Mr. Fothergill had shown them, were most valuable, as it was only by seeing what actually did occur that they could better provide for safety in the future. Prior to his appointment as general manager of the Leeds Forge Company Mr. Gearing had been a furnace user and a furnace buyer, yet after becoming thoroughly acquainted with the details of furnace manufacture he was of opinion that high tensile steel was not the proper material to make furnaces from. Much had been made of the fact that two corrugated furnaces, out of 2,400 supplied to the British Admiralty, cracked, and those two were of low tensile steel. He understood the cracking in these two furnaces was on the reverse flange at the back end, and it would be interesting to know whether the back ends of these furnaces were unduly worked during manufacture, and conse-

quently repeatedly heated and cooled, and also whether the corner of the reverse flange was of small radius, as, if so, it would assist to explain the accident. It was a matter of absolute fact that even with furnaces of low tensile or any other tensile, if they were so designed at the back ends as to necessitate repeated heating and cooling, and also if the corners of the reverse flange were sharp and not easy, that accidents were very liable to result. These two furnaces had now been replaced, and after the most severe treatment with forced draught and hammer testing they were quite satisfactory. Mr. Gearing informed him that the Leeds Forge Co. had made 27,000 furnaces of steel of from 23 to 26 tons tensile, and although there were cases of collapse due to excess of deposit, cracking was very uncommon, and it was since the use of the higher tensile that this had formed a recognised accident.

They all recognised in Mr. Hirst an engineer of great practical experience, and he, too, was very distinctly opposed to rigidity of design, and was of opinion that if they did not do something to admit of the coming and going of a boiler then there would be trouble in the future. He also very severely condemned excessive staying, but in this respect they were at the mercy of the requirements of the surveys. An instance of this rigid staying once came under his notice, in which the centre furnace of a double-ended boiler was so surrounded by stays that it hogged in the ashpit. He could not follow Mr. Hirst very clearly with regard to his opinion on flanging, but what he understood him to mean was that whilst a long flange was of advantage at the back end, they should not be so long as to necessitate undue thinning of the material. This difficulty had lately been overcome by the Leeds Forge Co., who now rolled their furnace plates about one-eighth thicker at the flanged end, so that when finished the flanged end was even thicker than the body, and the end flat much stronger than formerly. Mr. Hirst referred to the disgraceful treatment furnaces got in the boiler shop. Furnaces always would be subjected to more or less severe treatment by boilermakers, and this was still another reason why the material should be as ductile as possible. Not long ago he had a furnace which was found to be cracked in a corner on the reverse flange before being taken out of the truck; this was reported to the makers, and they gave it as their opinion that it must have knocked against something, and yet it was intended for use in a high pressure marine boiler. It should be stated, however, that the furnace was about 30 tons tensile.

In reply to Mr. Milton, he must at once take exception to his remark that he indirectly accused him of unfair dealings with the factors of safety of the various furnaces, as no one appreciated more than himself the responsibility of Mr. Milton's position, and his evident desire to extend the same degree of consideration to all. It was possible for anyone, however, to make an error of judgment, and, in his opinion, the factor diagram was an illustration of such errors. Mr. Milton was evidently inclined to favour the use of steel from 26 to 30 tons tensile as suitable for furnace manufacture, and whilst being favourably impressed by Mr Gross's views would like some other steelmaker to come forward and say which was right. Surely Mr. Milton did not propose to allow this most important question of suitability of material to remain until it was settled by the steelmakers. Marine engineers had proved by experience that the furnaces made during the last few years were faulty, but it was not their province to deal with the question of chemical analysis, but rather to insist on obtaining a material that would not fail. He, for one, did not propose to wait until the steelmakers said which was right, but rather to use material which had been proved to be successful. Mr. Milton referred to the fact that old boilers were successfully made of steel, but it should be remembered that the pressures, temperatures, and scantlings were now much greater than formerly, and consequently more was required of the material. With regard to the Admiralty, Mr. Milton said they used mild steel, and had as much trouble with their furnaces as anybody else. He distinctly denied this, as whatever might have been the trouble with Admiralty boilers their furnaces had been most successful, and as an engine builder he would rather adopt their specification for furnaces than any he had met with. As before explained, the trouble in the "Sybille" was evidently not due to faulty material, but apparently to rigidity of design, and formed an ample and valuable illustration of the valuable necessity of longitudinal elasticity. With reference to furnaces made of high tensile the firm with which he was connected some time ago addressed the following questions to the Leeds Forge Co., and received the following replies:—

Question.—What do you consider is the cause of cracking?

Reply.—One cause is undoubtedly due to excessive work put on the furnace in flanging, owing to some designs, this work resulting in repeated local heating; another cause is undoubtedly high tensile steel.

Question.—Had you as many failures when working on your low limit steel of 23 to 26 as now with 26 to 30 tons?

Reply.—No.

Question.—Do you consider the change in tensile as being a benefit or otherwise to the users of furnaces?

Reply.—It has been a benefit in the matter of first cost owing to a thinner furnace being used and necessarily a lighter one, but recent experience certainly points to the ultimate result being a distinct disadvantage.

Question.—Why did you change?

Reply.—The Board of Trade and Lloyd's having granted a higher formula to a competing furnace, said higher constant being obtained by using steel of not less than 27 tons tensile steel we were at a commercial disadvantage and were obliged to raise our tensile strength to the same level as our competitors.

Question.—Do you consider steel furnaces of say 28 tons tensile, which is the mean allowed by the Board of Trade and Lloyd's to be as safe from accidents as steel made of 23 to 26 tons?

Reply.—No.

Question.—Are your accidents in manufacture greater with from 26 to 30 tons steel than with low tensile steel?

Reply.—Yes.

Question.—Having regard to brittleness do you think it would reach its dangerous limit as soon with steel of from 23 to 26 tons as with steel of from 26 to 30 tons?

Reply.—Steel of from 23 to 26 tons would undoubtedly remain longer ductile than steel of 26 to 30 tons.

Those replies did not coincide with the opinions of Mr. Milton—viz., that very mild steel cracked when it lost its ductility, and that it lost its ductility quite as soon as any other.

The experience of the Leeds Forge Company was similar to that of Messrs. Schulz & Knaudt, but in their case the number of furnaces dealt with was 16,500, and whilst the 16,000 low tensile were most successful the remaining 500 made of steel above 26 tons were such a distinct failure that the firm positively refused to make any more In further reply to Mr. Milton's explanation of the factor diagram, he (Mr. Morison) repudiated any design whatever of attributing intentional unfairness to Lloyd's Registry, and he cordially endorsed Mr. Milton's remark that the reputation of Lloyd's Registry for perfect fairness was world-wide. In considering the strength of boiler furnaces it was fortunate they had actual results of experiments as their base, as they thus dealt with facts and not opinions. In the first place, Mr. Milton pointed out the percentage of difference between the best and worst results of the various furnaces, and showed that this variation was as follows:—

1892.—Fox experiments	17 per cent.
1888.—Farnley do.	20 „
1891.—Holmes do.	11 „
1886 and 1887.—Purves experiments ...	70 „
1889.—Purves experiments	20 „
1891.—Morison do.	4 „

This was graphically shown on diagram 18, and the noticeable fact was that the test results of the Morison furnace were the most uniform ever obtained, the difference between the best and the worst being only 4 per cent. or about seven times less than the mean variation of the entire series of tests of all the other types of furnaces. Mr. Milton stated that only furnaces of the same thickness could be illustrated by such a figure as the factor diagram, and that if selected tests were taken the basis of selection should be the same in all cases. He entirely agreed with this; indeed these were exactly his views, and as he particularly wished to illustrate everyday practice he adopted as his standard, or, as Mr. Milton would say, his "basis of selection," the thickness most nearly to that in actual use, consequently the factor diagram was calculated from the means of those test furnaces which were nearest to $\frac{9}{16}$ths in thickness. These were as follows :—

1890-1.—Fox tests	·5745.
1892.— do.	·5745.
1886.—Purves tests	·557.
1887.— do.	·612.
1889.— do.	·5815.
1891.—Holmes tests...	·536.
1886.—Farnley tests	·5535.
1891.—Morison tests	·5485.

He much regretted the way in which Mr. Milton referred to the *best* tests being taken in one case and the *worst* in others in order to prepare the factor diagram, as it unfortunately implied dishonesty of motive. Mr. Milton justly remarked that it was undesirable that an undeserved stigma should be allowed to be attached to Lloyd's Registry, to this he would add that it was equally undesirable that any undeserved stigma should be allowed to be attached to his paper, and with their permission he would now remove it, as it entirely arose from a misconception on the part of Mr. Milton. Referring to the factor diagram, Fig. 19, Plate XXXI., commencing on the left and dealing with the spots marked L only. Spots 1 and 2, Table II., page 133, referred to the Board of Trade official tests of the Fox furnace made at the Leeds Forge in 1890-91. The tests were most exhaustive, and were made regardless of expense. Test strips were cut in the presence of the Board of Trade officer, and sent direct to Messrs. Kirkcaldy, of London, and after the results were approved by the Engineer-in-Chief (Mr. Traill) the six plates were made into furnaces, all the operations being conducted under the supervision of a Board of Trade officer, and finally the furnaces were tested by Mr. Samson, chief assistant to the Engineer-in-Chief. Lloyd's were present at these tests, and took a copy of

the various results obtained by Mr. Samson. Table II. was therefore correct in every particular. The fifth and sixth tests being nearest to the average *commercial thickness* of $\frac{9}{16}$ths these were taken, and the mean of the two gave ·5745. The variation of 17 per cent. between the best and the worst of the six tests was explained in his paper, as one of the $\frac{5}{16}$ths plates was rolled thin at one edge, and when made into a furnace this thin edge became a flat on the furnace end, and as the thickness of this thin plain end was ·331, whilst the mean thickness of the body was ·378, the furnace naturally collapsed at the thin plain end, and this explained much of the 17 per cent. variation which Mr. Milton referred to. The mean tensile of the two tests taken was 28·98 tons, and as the Board of Trade demanded at the tests of the suspension furnaces that the tensile should be between 26 and 28 tons he took 27 tons as representing the latest official requirements as his basis, and reduced the tensile of the two tests in question with their corresponding collapsing coefficient to 27 tons in direct proportion in exactly the same manner as Mr. Milton did:—

$$29 : 27 :: C : C^1.$$

His paper described that the plain tubes were heated before being corrugated, and although they left the rolls red hot three out of the six were heated again for annealing purposes, and it was a noticeable fact that two out of the three furnaces which were annealed collapsed at the end flat, and the other on the first corrugation, so it would appear that the ends of the three furnaces which were annealed were well heated at that part, and the tensile thereby reduced. No. 3 spot, Table V., page 136, represented the result of the Board of Trade official tests on the Purves furnace in 1886. These tests were made with the same elaborate care as those previously described, the material being tested by Messrs. Kirkcaldy, and the experiments conducted by Mr. Samson. Two furnaces only were tested, the mean thickness being ·557, and as that thickness approached very nearly the $\frac{9}{16}$ths basis it may be inferred that the results represent the strength of the Purves furnace as manufactured for use in 1886. All the particulars of these two tests were therefore absolutely correct. No. 4 spot, Table V., represented the mean of two out of six tests made on the Purves flue in 1887. The two selected for calculating the diagram were as before, the nearest to the $\frac{9}{16}$ths basis, viz., the fifth and sixth which gave a mean thickness of ·612. These tests were carried out with the usual degree of excellence by the Board of Trade, and the whole of the results in Table V. were absolutely correct. Mr. Milton observed that "it is to be noted that those two tests are practically the worst of the six," thus insinuating that they were chosen for that reason. A very

little consideration would have shown Mr. Milton that his conclusions were entirely wrong, and prevented him from making this unwarranted accusation. His remark simply draws attention to the fact that by choosing as a basis the furnace having a thickness most nearly approaching that in general use they got with the Purves design a furnace of the lowest relative strength. He pointed out that physical fact in his paper, and illustrated it very clearly in Fig. 18, Plate XXX., a reference to which would show that the weakness was no mere accident of experiment, but a direct consequence of the reduction in the proportion in the material in the stiffening ribs to that in the plain part. It could not be disputed, however, that the results of the two tests he took corresponded to those that would be obtained from furnaces manufactured for use at that date, and that alone would justify his position. Mr. Milton said these 1886 and 1887 tests on the Purves flue were unknown at Lloyd's, but this did not alter the fact that they represented the true state of the manufacture at that date. One test only appeared to have been made for Lloyd's in 1886, but in view of the Board of Trade tests made in 1887 its correctness was doubtful, and he did not include it in his paper. Spot 5, Table VI., page 137, represented a mean of two of six tests made by the Board of Trade only on the Purves furnace in 1889, and, as before, he took the mean of the two furnaces nominally $\frac{9}{16}$ths thick for calculating the diagram. It would be observed that the table was very incomplete, and although he applied to the Board of Trade for particulars he failed to obtain them. He also wrote to Messrs. John Brown & Co., and they very kindly sent him the tensiles of the test pieces cut from the plates from which the six furnaces were made, at the same time explaining that they could not give him the remaining particulars as they had no record. Some time after he found these tensiles did not agree with others he obtained, and he wrote Messrs. John Brown & Co. the second time asking them to examine their records again, as he wished the table to be absolutely accurate, to this Mr. Gross kindly replied confirming the tensiles before given, the mean of which is 28·25 tons. These tensiles were therefore correct, but they could not tell how or where the furnaces collapsed, or whether the furnaces were heated for rounding up and again heated for annealing or whether heated once only. In either case, however, the tensiles *corresponded to those of the original plates* as in all the other cases. With reference to these tensiles Mr. Milton said—"The records given by Mr. Morison of the tensile strengths of the steel used in these furnaces is not in accordance with the information we have which led us to take 27·2 tons

as the mean strength of the tests." It would be noticed Mr. Milton did not say 27·2 was correct, but that he was "led to take it," yet on this assumption the calculation regulating the manufacture of the furnace seemed to have been based. It would be interesting to know whether the 27·2 represented the tensile of the furnace after annealing, but even if that was the case it was still wrong, as the tensiles of all the other tests were taken from the plates after rolling and before they were made into furnaces; indeed in the Board of Trade experiments no progress was made with the manufacture of the test furnaces until Mr. Traill approved of the tensiles of the test strips. The one test made by Lloyd's in 1890 being incomplete, and the tensile strength being unknown, he thought it better to make no assumption as the six Board of Trade tests afforded all the data necessary for accuracy. Spot 6, Table IV., page 135, represented two out of three tests made by the Board of Trade on Holmes's furnaces. This table was revised by Messrs. Holmes & Co., and was correct. The tests taken were the second and third which gave a mean thickness of ·536. Spot 7, Table III., page 134, represented two out of five tests made by the Board of Trade on the Farnley furnace, the two taken being the first and second as giving the nearest mean thickness of $\frac{9}{16}$ths. The table was submitted to the Farnley Iron Co. and returned as correct. The diameters were the subject of special correspondence, and he was assured by the Farnley Co. that they were correct, consequently Mr. Milton would appear to be wrong. No record was kept of the tensiles, but the makers advised him that by taking 28 tons it would be approximately correct, and as Mr. Milton also assumed the same it in no way affected the argument. Spot 8, Table VII., page 138, represented two out of six experiments made by the Board of Trade on the Morison furnace in 1892. The Appendix contained a detailed report on these tests, the accuracy of which could not be questioned, as every detail of manufacture was supervised by a special Board of Trade officer. The test strips cut from the plates gave a mean tensile of 27·2, and it was worthy of special notice that these plates were twice heated after the test strips were cut, once before being corrugated and the second time after corrugation, this final annealing being watched by Mr. Samson, who made a special visit to the Leeds Forge for that purpose, consequently the tensiles of the furnaces as tested would undoubtedly be lower than 27·2 tons. It would be observed that two of the six collapsed at the end flat, as against three out of six in the Fox, and the length of the flat was practically 5 inches against 6 inches in Fox. This difference of 1 inch was made much of by Mr. Milton, although he was very

careful to deal fully with the question of flats on surface ends in his paper, giving a diagram of those test furnaces which had failed at the flat. All engineers would agree that long flats on the back top end were undesirable, but if the furnace was made for removal on Ashlin's plan, or that adopted by Messrs. John Brown & Co., there need be practically no flat at that part, the radius of the saddle flange sweeping into the radius of the first corrugation, the design of the suspension furnace being particularly suited to this arrangement, the long suspension curve being continued into that of the saddle flange so that no abrupt cavity existed. In furnaces which were not designed for removal it was necessary to leave about $2\frac{1}{2}$ inches of the flat on the top back end, so as to make a joint if the furnace had to be cut out at any time. The next important flat was at the front too, but in no case in the suspension furnace need this exceed $4\frac{3}{4}$ inches, as when it did the makers rolled in a Fox corrugation. There remained, therefore, only the flat at the bottom back end, and even this was only about 6 inches long, and being below the line of fire and behind the bridge it did not accumulate scale, and therefore retained its original factor of safety. Mr. Milton's contention was, that if the Morison test furnaces had had the same length of flat as the Fox, viz., 6 inches instead of 5 inches, they would have given equal results, and went on to say that a 6 inch flat was necessary for practical requirements. Let them assume for argument that a 6 inch flat was a necessary standard. The question then arose that if the body of a furnace had practically the same resistance to collapse as a plain part at the end 6 inches in length, was there any benefit to be derived from making the body stronger? His opinion was, that if the body of a furnace could be made stronger than the 6 inch plain part at the end, that it was a stronger furnace as a whole, as the centre of the furnace, or that part above the hottest part of the fire, was certainly the weakest in actual use, and should be the strongest under cold water test. If they examined the Fox tests they found three furnaces collapsed on the flats and three on the body, thus it would be reasonable to assume that the body of a Fox furnace was equal in strength to a plain end 6 inches in length. The question now was to determine whether the body of a Morison furnace was stronger than a 6 inch flat. It would be seen on reference to Fig. 23 that the mean length of flats of the three Fox tests which collapsed on the flats was $6\frac{3}{16}$, and the mean collapsing coefficient 80,850, consequently, had the mean length of the flats on the Morison furnace been the same, the collapsing coefficient would naturally also have been about the same, but the mean collapsing coefficient (calculated on the outside diameter) of the 2nd, 3rd, 4th, and 5th Morison tests, all of

which failed on the body, was 89,537, consequently, had the suspension test furnaces had a length of 6 inches, they would all have failed on the flat, and therefore the body of a suspension furnace was proved by these tests to be stronger than a 6 inch flat on the end, and therefore stronger than the body of a Fox furnace. But Mr. Milton said nothing about the flats in the Farnley or the Purves, although the 1887 experiments of the latter showed that a flat of 7½ inches long was stronger in every case than the ribbed body, and still further in the 1890 Purves experiments, Mr. Milton admitted that he knew nothing of the position of the collapse, whether on the flats or in the body, and yet he would seem to depreciate the value of the suspension tests, but no statements or opinions could alter the fact that they were the most uniform tests ever made, varying only (according to Mr. Milton's own figures) 4 per cent. between the best and the worst, and also that on an equal tensile they gave the highest resistance to collapse on record. The general accuracy of all the tables having been proved, he would now show by an illustrative example how the Lloyd's spots were calculated. Take Table II., page 133, for this purpose, and select the two tests nominally $\frac{9}{16}$ths thick, viz., the 5th and 6th. The dimensions were—thickness, ·574 and ·575; diameter over corrugations, 35·593 and 36·937.

Apply Lloyd's 1892 rule for corrugated furnaces, which was:—

$$\frac{1{,}259\ (t - 2)}{D} = \text{working pressure.}$$

Where t = thickness in sixteenths of an inch.

$$(1) \quad \frac{1{,}259\ \left[(16 \times \cdot 574) - 2\right]}{35 \cdot 593} = 254 \cdot 1.$$

$$(2) \quad \frac{1{,}259\ \left[(16 \times \cdot 575) - 2\right]}{36 \cdot 937} = 245 \cdot 4.$$

And by dividing the actual collapsing pressures by these working pressures they got the factors of safety thus :—

$$(1) \quad \frac{1{,}400}{254 \cdot 1} = 5 \cdot 51\ ; \qquad (2) \quad \frac{1{,}410}{245 \cdot 4} = 5 \cdot 74\ ;$$

which gave a mean factor of safety of 5·63. But this was on a basis of steel having a tensile of 28·98 tons, consequently the factor, when reduced to a basis of 27 tons, became :—

$$\frac{5 \cdot 63 \times 27}{28 \cdot 98} = 5 \cdot 24.$$

All the remaining spots were calculated in exactly the same manner, and full particulars would be found in Table VIII. He would now apply

Mr. Milton's method of calculation to the factor of safety diagram which represented the factor of safety on the furnaces *when new*. Taking the symbols in the tables they had :— $C = \frac{P \times D}{T}$ or $P = \frac{C \times T}{D}$; also let p = Lloyd's working pressure $= \frac{\text{Lloyd's constant } (t - 2)}{D}$ where t = thickness in sixteenths of an inch. Hence, since $\frac{P}{p}$ = factor of safety

$$\text{Factor of safety} = \frac{C \times T}{\text{Lloyd's constant } (t - 2)} \text{ or}$$

$$\text{Factor of safety} = \frac{C \times T}{\text{Lloyd's constant } (16\ T - 2)}$$

where T = thickness in inches. If the factors of safety were now calculated by this formula they would get results identical with those given in Table 19 (Lloyd's) and as calculated above. For instance, referring again to Table 2 (Lloyd's) they found that the factors of safety were :—

$$(1) \qquad \frac{1{,}400}{254{\cdot}1} = 5{\cdot}51; \text{ and } \frac{1{,}410}{245{\cdot}4} = 5{\cdot}74;$$

$$(2) \text{ also factor of safety} = \frac{C \times T}{\text{Lloyd's constant } (16\ T - 2)};$$

substituting the values for C and T they got:—

$$(1) \quad \frac{86{,}812 \times {\cdot}574}{1{,}259 \times \left[(16 \times {\cdot}574) - 2)\right]} = \frac{86{,}812 \times {\cdot}574}{1{,}259 \times (9{\cdot}184 - 2)} = 5{\cdot}51;$$

$$(2) \quad \frac{90{,}576 \times {\cdot}575}{1{,}259 \times \left[(16 \times {\cdot}575) - 2\right]} = \frac{90{,}576 \times {\cdot}575}{1{,}259\ (9{\cdot}2 - 2)} = 5{\cdot}74;$$

which were precisely the same results as above. Mr. Milton explained that Lloyd's rule contained the expression $(t - 2)$, where t was the thickness in sixteenths of an inch, and that this $\frac{2}{16}$ths represented an allowance for corrosion. Now, let them ascertain the factor of safety in the same furnaces when reduced $\frac{1}{8}$th by corrosion, this made the $\frac{9}{16}$ths furnace into a $\frac{7}{16}$ths, and reduced the diameter by a $\frac{1}{4}$ inch. In furnaces of equal thickness they could take the nearest actual tests to the $\frac{7}{16}$ths for the purpose, but in a Purves furnace there would be an undue advantage given to it by the additional material in the rib of a $\frac{7}{16}$ths new furnace beyond that of a $\frac{9}{16}$ths when corroded $\frac{2}{16}$ths. As it was necessary to deal with actual test results, however, they might ignore this advantage thus gained by the Purves, and then calculate the factors of safety as follows :—

The equation becomes:—

$$\text{Factor of safety} = \frac{C \times T}{\text{Lloyd's constant } (t - 0)}$$

$$= \frac{C \times T}{\text{Lloyd's constant } (16\ T - 0)} = \frac{\text{collapsing coefficient}}{16 \text{ Lloyd's constant}};$$

which is exactly the equation Mr. Milton used. In order that there might be no assumptions, he would take the nearest actual tests to $\frac{7}{16}$ths, and would refer again to Table II. The tests nearest $\frac{7}{16}$ths in thickness were the third and fourth, viz., ·452 and ·468. The collapsing coefficients would be:—

$$(1)\ \frac{35{\cdot}625 \times 1{,}130}{{\cdot}452} = 89{,}000; \quad (2)\ \frac{36{\cdot}469 \times 1{,}000}{{\cdot}468} = 85{,}000;$$

and reduced to steel of 27 tons:—

$$(1)\ \frac{89{,}000 \times 27}{29{\cdot}26} = 82{,}200; \quad (2)\ \frac{85{,}000 \times 27}{29{\cdot}02} = 79{,}000.$$

$$\text{Factor of safety} = \frac{C}{16 \text{ Lloyd's constant}} = \frac{C}{16 \times 1{,}259}.$$

$$(1)\ \text{Factor} = \frac{82{,}200}{16 \times 1{,}259} = 4{\cdot}08; \quad (2)\ \frac{79{,}000}{16 \times 1{,}259} = 3{\cdot}92;$$

which gave a mean of 4·0. All the other tests had been treated in the same way, and the results were shown in Diagram C, Plate XXXIX. In addition to Diagram C, he had calculated a second, Diagram D, Plate XXXIX., on the *means* of all the furnace tests, except the $\frac{5}{16}$ths Purves, as proposed by Mr. Milton, and he had reduced all these to a basis of steel having a tensile strength of 27·2 tons per square inch, which was Mr. Milton's basis. Taking the Fox tests with Lloyd's 1892 rule as before, they had for new furnaces:—

$$\frac{C \times T}{1{,}259\ (16\ T - 2)} = \text{factor of safety},$$

and calculating the factors of safety by this formula they got the following:—6·65, 5·68, 6·12, 5·75, 5·5, and 5·74, which gave a mean of 5·9, and reducing this to steel of 27·2 tons tensile they got:—

$$\frac{5{\cdot}9 \times 27{\cdot}2}{29{\cdot}07} = 5{\cdot}52.$$

For furnaces after corrosion had taken place to the extent of $\frac{1}{8}$th, the formula became:— $\dfrac{C}{1{,}259 \times 16} = \text{factor of safety}.$

The mean collapsing coefficient for the six furnaces was 85,691, and substituting this value they got:—

$$\frac{85{,}691}{1{,}259 \times 16} = 4{\cdot}25,$$

and reduced to steel of 27·2 tons tensile:—

$$\frac{4{\cdot}25 \times 27{\cdot}2}{29{\cdot}07} = 3{\cdot}98.$$

All the other spots had been calculated in exactly the same manner. He might add that all his calculations had been made with the slide rule, so that possibly in some cases the second and third decimal places in the factors of safety might not be quite accurate. However, this would not materially affect the diagrams. In comparing the formulæ of the Board of Trade and Lloyd's it would be seen that the $(t - 2)$ in the rule of the latter had the effect of giving a premium to thick furnaces; for example, take a Purves furnace 36 inches inside diameter and $\frac{7}{16}$ths thick, the working pressure allowed by the Board of Trade for steel from 26 to 30 tons would be 166·3, and by Lloyd's 157·5, or a difference of 8·8 lbs. per square inch in favour of the Board of Trade. Now take the same furnace $\frac{5}{8}$ths thick, the Board of Trade working pressure would be 235 and Lloyd's 249, being a difference of 14 lbs. in favour of Lloyd's, or a total difference of 22·8 resulting from the application of Lloyd's formula. But in the Purves design they knew that the thicker furnace was relatively the weaker, so the wisdom of the rule applied to this particular design was doubtful. Mr. Milton explained this $(t-2)$ in its general application to all furnaces, by saying that the strength of a thick furnace was affected less by corrosion than a thin one, but when it was remembered that modern furnaces had a thickness ranging only from about $\frac{1}{2}$ inch to $\frac{3}{4}$ inch, it would seem preferable that the factor of safety should be calculated on the furnaces when new and made sufficiently large to allow for corrosion. In concluding his reply to Mr. Milton, he wished particularly to state that he did not in anyway criticise the *amount* of the factors of safety, as there was no doubt whatever that the factor of safety on furnaces was less than in any other part of the boiler. In 1888, when the Engineer-in-Chief of the Board of Trade reported on the successful working of the 27,000 Fox's furnaces made between 1879 and 1888 and manufactured of low tensile steel, they had had for many years practically 80 lbs. steam pressure and little or no forced draught. Now, they had pressures of 160 to 200, and a good deal of forced draught, consequently the factor of safety should be even greater now than then. Take for example the American liners: it was quite a common occurrence for some of the furnaces to be set up at the end of a voyage, showing the factor of safety had entirely disappeared. Consequently, he was certainly of opinion that in forced draught boilers especially, where the temperature was excessive and the liability to scale correspondingly great, the factors of safety allowed both by the Board of

Trade and Lloyd's were by no means too large. His contention was not that they were too large in amount, but that they were not equal for all designs of furnaces, and that they should be made equal in justice both to users and manufacturers. Another point was, it would appear to be desirable that the factors of safety should be based on the lowest limit of the range of tensiles. For example, take the ranges to be from 23 to 26 tons and from 26 to 30 tons, the factor of safety should undoubtedly be based on the 23 tons in the former case and on the 26 tons in the latter, and not on the means of the range.

Mr. Patterson was very definite in his views regarding the necessity of breathing room in boiler design, and rightly so, as it was evidently the result of practical experience. Mr. Patterson emphasized the importance of long flanges and easy bends, and objected to being compelled to surround furnaces with more stays than was good for them. Both Mr. Patterson and Prof. Weighton referred to the factor diagram, but this he had dealt with fully in his reply to Mr. Milton. Apart from all other considerations, they as marine engineers naturally relied on the formulæ of the Board of Trade and Lloyd's as representing faithfully the comparative strengths of furnaces; indeed they had no other alternative, as the tests not being published, they were practically compelled to follow the rules blindly. If, however, the tests made by the Board of Trade for the public benefit were accessible to the manufacturing community each could then judge for himself, and if he considered the factor of safety too small in any particular instance, he could increase it at his discretion. Then came the question of giving all manufacturers equal advantages, but that was a commercial question and outside the limits of the paper.

Mr. Sivewright's remarks were of considerable value as they also represented the results of practical experience. Mr. Sivewright drew particular attention to the necessity of subjecting steel to cold-bending tests. An illustration of this was the specimen before them, which was from a plate intended to be used in the construction of a ship. On the plate being put into the machine for the purpose of cold flanging it cracked with a loud report the whole length of the plate (viz., 8 feet) before the angle of bend exceeded 10 degrees. The mechanical test from the plate close to the fracture gave a tensile of 31½ tons per square inch, whilst the most noticeable feature in the chemical analysis was an excess of phosphorus. Mechanical tests were made at another portion of the plate and were most satisfactory, the material being so good that it could be bent double without fracture. This was an illustration of the fact

that phosphorus in steel was erratic in its position and amount, and if the test strip from a plate containing an undue amount happened to be taken from the plate where there was but little phosphorus the test would be satisfactory, yet the plate as a whole might be entirely unfit for use. Mr. Shute, as a manufacturer of furnaces, pointed out the fact that the greater the amount of work put on a furnace at the back end the greater was the liability of ultimate failure. It would therefore seem of advantage that flanging should be done by hydraulic pressure and not by hand, as not only would this reduce the number of heatings and coolings, but it would subject the material to the minimum amount of distress. Mr. Spence referred to the welding of furnaces to tube plates. He did not think this practice would become popular, but there was no doubt that with such an arrangement it was highly necessary to use steel of the best quality and of low tensile, and also to thoroughly anneal the structure when finished.

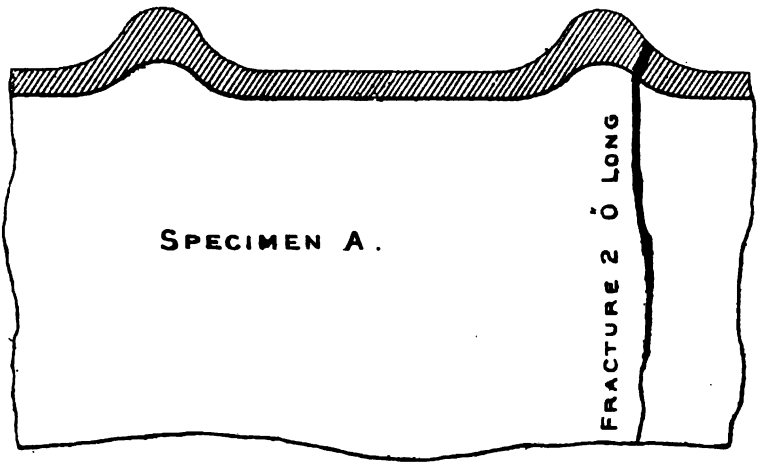
Few men had had greater opportunities of examining furnaces under all conditions of working than Mr. Geddes, and he also was in favour of steel below 26 tons tensile. The opinions of the Liverpool surveyor to Lloyd's Registry regarding the risk incurred by heating high tensile furnaces when setting them up were most valuable, as they were undoubtedly based on very large experience, which was after all the sure guide to success. Mr. Walliker stated that plain furnaces were passed by Lloyd's, 41 inches external diameter for 160 lbs. pressure, but it should be noted that they would require to be made of the material which Mr. Taylor said had caused untold annoyance and expense to all concerned; so the wisdom of fitting such a furnace after such an opinion from an engineer of Mr. Taylor's experience and reputation would be, indeed, doubtful. All engineers would agree with Mr. Walliker that the internal stresses on a boiler were considerable, and there was no doubt that the centre furnaces of a boiler were more severely strained than those at the wings, but did not this point to the necessity of using the most ductile material, and also providing for elasticity in design? He did not agree that entire immunity from furnace accidents depended on the practice of boiler builders, but often on the care exercised by boilermakers in inspecting furnaces carefully on delivery, but now that Lloyd's tested the material and surveyed the furnaces at the works of the makers before delivery to the boiler builders, accidents in the future would unquestionably be lessened. He did not understand Mr. Walliker's conversation with Mr. Fothergill with reference to the cracked specimens being from forced draught boilers; surely forced draught

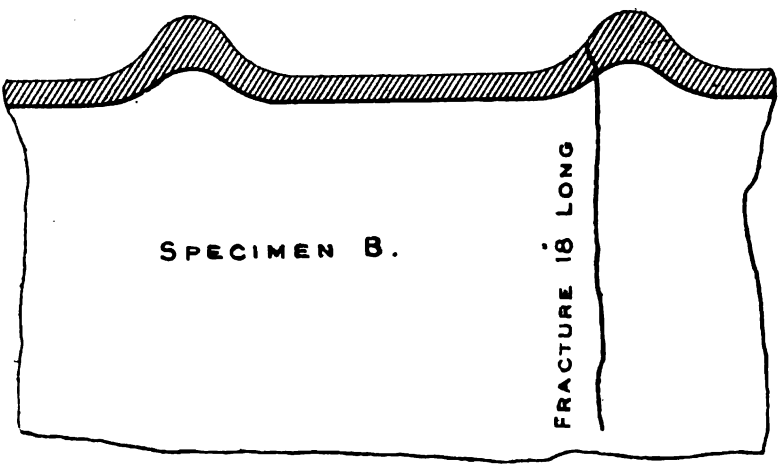
should not result in furnaces ripping or exploding, but he could quite understand that forced draught caused greater stresses on the furnace than natural draught, but material should be used which would successfully withstand them, and it should be noted that the steel of the furnace in question was over 28 tons tensile. Other furnaces had ripped in exactly the same manner, however, with natural draught. Mr. Walliker and others had objected to the terms high and low tensile; his reason for adopting this in his paper was that the Board of Trade and Lloyd's whilst recommending steel of about 28 tons for furnaces admitted two ranges, viz., from 22 to 26 tons and from 26 to 30 tons (see Diagrams A and B, Plate XXXVIII.), and as a matter of convenience he had distinguished them by the terms low and high tensile. He did not quite follow Mr. Walliker with regard to the two plates of different thickness rolled from the same ingot, as it was not customary for steelmakers to roll plates of great difference in thickness from the same ingot, but to proportion the carbon in an ingot to suit plates of a predetermined thickness and tensile.

He would again thank the several gentlemen who had assisted him in the preparation of the paper, and also those who had taken part in the discussion. He had endeavoured to render his reply as complete as possible, his object being to give the Institution as much information on the furnace question as he had been able to obtain, and if the paper resulted in the slightest benefit to marine engineering his desire in its preparation had been realised.

Mr. MILTON moved a vote of thanks to Mr. Morison for his paper, which was adopted by acclamation.

To illustrate Mr. J. R. Fothergill's remarks on page 177.





ON APPARATUS FOR DETERMINING THE AMOUNT OF WATER SUSPENDED IN STEAM.

By W. R. CUMMINS.

[Read before the Institution in Newcastle-upon-Tyne, on Monday, January 30th, 1893.]

The object of this short paper is to raise a discussion on the different methods adopted at engine and boiler trials for measuring the amount of water suspended in the steam supplied to the engine. In the first place, the writer considers it almost unnecessary to point out the enormous value of engine and boiler trials, such as those carried out during the past few years by the Institute of Mechanical Engineers.

Trials of this kind, if properly carried out, have a use quite apart from their scientific interest, as they enable the engineer to see the weak points in the system under trial, point out in what manner it is better than that which it has superseded, and, most important of all, indicate the direction in which further improvement may be made.

To obtain a real comparison between different types of engine and boiler, it is very necessary to separate the different efficiencies which go to make up the total efficiency of any combination.

The efficiency of a boiler is made up of the efficiency of the furnace and the efficiency of the heating surface.

The efficiency of an engine is made up of the efficiency of the steam and the efficiency of the mechanism.

The measurements usually made at trials of marine machinery are: weight of coal burnt, analysis and calorific value of coal, analysis and temperature of funnel gases, indicated horse-power, weight of water pumped into the boiler, and amount of "priming" water delivered to the engines. In the opinion of the writer this last measurement is of the greatest importance, as, without it, it is impossible to separate the efficiency of the engine from that of the boiler, and, moreover, all calculations as to the condensation and re-evaporation in the cylinders effect of jackets, etc., can only be based on guesswork.

A notable instance of how priming may vitiate trial results occurred at the Mechanical Institute's trial of the S.S. "Tartar."

No means were taken at this trial for measuring the amount of priming, the steam being assumed to be practically dry. On making the calculations after the trial it was found that the efficiency of the boilers was unexpectedly high, and that of the engines unexpectedly low (on the assumption that all the water pumped into the boilers was turned into steam). A very complete analysis of the waste gases, however, had been made, which enabled the Research Committee to state that a considerable amount of priming had taken place, probably amounting to about 20 per cent. of the total feed.

In this instance the amount of water present in the high pressure cylinder amounted to no less than 55 per cent. of the total steam and water passing through it, and on referring to the reports of the other trials it will be seen that the amount of water present at various stages often reaches 40 or 50 per cent., and this water is all or nearly all suspended in the steam in a very fine state of division, as is seen when the indicator cock is opened and the mixture of steam and water allowed to blow through it.

The lessons taught by this trial are:—1st, That it is impossible to gauge the wetness of steam by its apparent condition at the indicator cock; and 2nd, that the ordinary marine boiler may under no apparent provocation deliver steam containing as much as 20 per cent. of water. May this last fact not throw some light on the otherwise inexplicable anomalies as set forth in the recently published report of the Research Committee on the "Efficiency of Steam Jackets?"

Before proceeding to describe the various apparatus, it might be well to make some enquiry into the nature of priming. Priming may be due to two actions: the first of which may be described as being entirely mechanical, that is to say, the particles of water projected into the steam space of a boiler by the ascending bubbles of steam become wholly or in part suspended in the steam. The second cause is due to insufficient absorption of heat, which latter may be due to two causes. Take the case of an isolated drop of water at the same temperature as the steam. This drop may receive enough heat to turn the whole of it into steam, and may take up a certain quantity of water before it reaches the steam space, or it may reach the steam space without having received sufficient heat to turn the whole of it into steam.

It does not seem possible to estimate how much each of these causes affects the total amount of priming, but it seems probable that the second

cause should depend upon the disposition of the heating and water surfaces and the temperature of the gases, and that the erratic nature of priming should be due to the first-mentioned cause.

The presence of grease in a boiler often causes priming: can it be that greasy steam is capable of holding more water than clean steam? Perhaps particles of grease in the steam space act as nuclei round which water will collect.

Among the first attempts made to measure the water contained in steam was that by means of an apparatus called the "barrel" calorimeter.

It consists of a vessel (probably originally a barrel, hence the name) containing a known weight of water at an observed temperature. The steam to be tested is led to the bottom of the vessel, thus passing through the water and becoming condensed. At the end of the test the increases of weight and of temperature are noted, and from these data and a table of the properties of steam the amount of water in the steam may be calculated.

This apparatus has many disadvantages. In the first place a correction must be made for radiation from the apparatus and for the amount of heat absorbed by it; and in the second place a correction must be made for any evaporation which may take place from the surface of the water.

Although this latter may be neglected if the final temperature be kept sufficiently low, the corrections for radiation and absorption present a good many difficulties, entailing tests on the apparatus to determine the loss of heat under varying conditions, such as different temperatures of atmosphere and different durations of test.

The greatest disadvantage of this apparatus, however, for use on board ship would be the difficulty of weighing with sufficient accuracy.

The next method to be considered is that of the salt test, which is carried out as follows:—A sample of water is taken from the boiler, and the percentage of salt held in solution is determined with great accuracy. A sample of steam from the steam pipe is at the same time collected in a small special condenser, and the percentage of salt in it is determined by chemical analysis, as in the case of the water from the boiler. From these data the amount of priming water may be calculated.

This method should give accurate results for what the writer has called "mechanical" priming, provided the sample of water were taken from the right place, viz., near the water-surface, but it is not at all certain that it would give reliable information as regards the other kind of priming; in short, the truth of the result of the calculations depends upon the assumption that the whole of the salt in solution is precipitated at the moment the water assumes the gaseous form.

Take the case of an isolated drop of water at the temperature of evaporation, and suppose it to contain 5 per cent. of salt in solution. Let it receive enough heat to turn three-fourths of it into steam, then if at the moment of gasification the drop of water contained 5 per cent. of salt the resultant steam would contain $5 \div 4 = 1\frac{1}{4}$ per cent. of salt. If, on the other hand, some of the salt were precipitated before the moment of gasification—suppose, for instance, that $2\frac{1}{2}$ per cent. were thus precipitated—then it is evident that the steam would only contain $\frac{5}{8}$ per cent. of salt instead of $1\frac{1}{4}$ per cent. as before. The writer is not aware of any experiments on the behaviour of salt in a solution of water subjected to gradual heating and evaporation, but if the whole of the salt does not remain in solution until the moment of gasification, then the results will be inaccurate to an extent which cannot be easily estimated, as it depends upon two factors: first, the proportion of each kind of priming, and secondly, the amount of precipitation before gasification. In this connection it will be well to note the length of time the water remains in the boiler. Take the case of the Mechanical Engineers' trial of the paddle steamer "Ville de Douvres." The boilers contained $61\frac{1}{2}$ tons of water = 137,760 lbs. Total feed per hour = 66,180 lbs.

$$137{,}760 \div 66{,}180 = 2 \text{ hours about.}$$

It is thus easy to imagine that at any moment there may be a certain portion of the water in the boiler (viz., that which is on the point of being turned into steam) containing a less percentage of salt than the body of water from which the sample is taken. Another source of error may be introduced when more than one boiler is supplying steam and only one condenser is used on the main steam pipe, for it is evident that if the boilers have different percentages of salt and one boiler does more priming than the other an error will be introduced. Hence, when more than one boiler is in use a separate sample should be taken from each branch pipe. Taking these points into consideration, it appears to the writer that the salt test would not be sufficiently reliable for accurate results, the probability being that the amount of water in the steam would be underestimated.

The next apparatus to be considered is the Barrus calorimeter. The action of this instrument is based on the fact that if steam be allowed to expand without doing external work, it will become superheated; that is to say, the heat which would be transformed into work if the steam were expanding and doing work on a piston is expended internally, viz., by heating itself, or by evaporating any contained water.

The apparatus consists of a tube A (see Plate XL.) having its end closed

by a diaphragm B, perforated with a small hole. The steam to be tested is led from the steam pipe C to the tube A, from whence it escapes to the atmosphere through the small hole in the diaphragm by means of the tube D.

A pressure gauge E and thermometer F are inserted in the tube A, and a thermometer G in the tube D. Suppose the steam to be of 150 lbs. pressure: then if it were dry, saturated, and no heat were lost by radiation, the amount of heat available for superheating would be 1,225 — 1,178 = 47 thermal units = difference of total heat of steam at 150 lbs. pressure, and steam at atmospheric pressure. Specific heat of superheated steam = ·48. Hence amount of superheat $= \frac{47}{\cdot 48} = 98$ degs. Fah. approximately. So that the thermometer in the tube D would indicate 212 degs. + 98 degs. = 310 degs. Fah.

Next, suppose the steam to contain 5 per cent. of water, then total heat of steam and water at 150 lbs. pressure—

$$= (\cdot 95 \times 1225) + (\cdot 05 \times 370) = 1{,}182 \text{ thermal units.}$$

Total heat at atmospheric pressure if all water be evaporated = 1,178 thermal units. Difference = 4 thermal units, available for superheating. Amount of superheat $= \frac{4}{\cdot 48} = 8$ degs. Fah. Hence thermometer in tube D would indicate 212 + 8 = 220 degs. Fah.

It will be seen at once that this apparatus is very sensitive to small variations in the percentage of contained water; for example, with steam of 150 lbs. pressure there is a difference of 90 degs. Fah. for 5 per cent. of water, but on the other hand, it has only a limited range; for instance, with steam of 150 lbs. pressure the range is limited to about 5 per cent. of water, without taking account of radiation, as 6 per cent. of water reduces the heat available for superheating to a negative quantity, and at 80 lbs. pressure the range is practically limited to 3 per cent. of water.

An attempt has been made to get over this difficulty by fitting what is called a "drip box," H, as shown in Plate XL., the function of which is to intercept as much as possible of the contained water.

The water collected in this box is drawn off at intervals and weighed, and the proportion which this latter bears to the total quantity of steam passing through the instrument is added to that calculated from the amount of superheat.

The quantity of steam passing through the small hole is determined by experiment for each apparatus, the steam being led to a condenser, collected, and weighed. This seems to be a very rough and ready way

of calculating what, in a great number of cases, will be the greater proportion of the contained water, unless very careful experiments are made to determine the weight discharged under every condition of steam pressure, atmospheric pressure, and wetness of steam. This defect, however, could be remedied by always using a condenser in connection with the apparatus, and the addition of an air-pump for maintaining a vacuum in the condenser would increase the range of the instrument; thus for steam of 150 lbs. pressure and a vacuum corresponding to 2 lbs. absolute pressure the range would be increased from about 5 per cent. of water to about 8 per cent. of water. It seems probable that the drip box under certain conditions would not be able to intercept a sufficient proportion of the suspended water. In this case a centrifugal separator might be used to replace the drip box.

When using this apparatus a certain allowance must be made for radiation, and the difficulty of estimating this allowance will always leave some doubt as to the correctness of the results. There is a certain amount of heat available for evaporating the moisture and superheating the steam, and this is distributed between the steam and the material of the apparatus.

If the steam be of constant quality the apparatus will after a time arrive at a normal temperature, and the only heat not given to the steam will be equivalent to that lost by radiation to the atmosphere.

If, however, as will probably be the case, the percentage of water be continually varying, the thermometer in the tube D will not give correct readings, as it will be influenced by heat given out and taken up by the material of the apparatus; that is to say, the thermal capacity of the apparatus will tend to lessen the oscillations of the thermometer G, and thus lead to erroneous results.

Taking the above points into consideration it appears to the writer that the Barrus calorimeter should give fairly accurate results for high pressures and small percentages of water, but for low pressures or large percentages of water it would require considerable modification to make it generally useful.

In order to overcome the difficulties connected with the three methods described above, the writer has designed the apparatus shown in Plate XLI. It consists of a cylinder A filled with a number of small tubes fixed in the tube plates B. A jacket D is cast round the barrel, and the covers C form jackets for the ends.

The principle of the action of the apparatus is to evaporate the water contained in a sample of the steam under test, in a vessel of fixed volume.

When all the water is evaporated the increase of pressure is noted, and a simple calculation gives the percentage of water originally in the steam.

The heat required for thus evaporating the water contained in the sample of steam is supplied by admitting to the jacket steam of higher temperature than that of the sample in the cylinder.

When the steam to be tested is of boiler pressure, and no higher pressure is available, a small steam ram pump may be used to pump steam of the required pressure into the jacket.

The point at which all the water in the sample is evaporated is determined by the fact that superheated steam has a lower pressure than saturated steam of the same temperature. Hence, so long as the pressure of steam in the cylinder and that in the jacket (which is kept saturated) is the same, it will be known that the sample steam is saturated, but as soon as the pressure in the cylinder falls below the pressure in the jacket, then it will be known that all the water has been evaporated and the sample will be superheated.

On top of the apparatus is an attachment E for detecting very small differences of pressure between the cylinder and the jacket. It consists of a thin diaphragm F of corrugated steel, one side of which is in connection with the sample steam in the cylinder, and the other side is in connection with the jacket.

Immediately the pressure in the cylinder falls below that in the jacket, the movement of the diaphragm breaks an electric circuit and cuts out a bell.

The operation of testing a sample of steam would be as follows:—First, the jacket and cylinder would be opened to the steam to be tested, so that the whole of the surfaces would be brought to the same temperature as it. The outlet valve G would then be opened and the inlet valve H closed, so that any water adhering to the surfaces would be evaporated, and enough steam blown through to ensure a fair sample of steam being in the cylinder. The outlet valve G would then be closed, and then the inlet valve H. The pressure in the jacket would then be gradually raised until the bell ceased ringing, which would indicate that all water had been evaporated.

As regards the probable accuracy of results obtained from this apparatus, the first point to be considered is the reliability of the data at our disposal on the density of saturated steam at different pressures.

This has not yet been experimentally determined, but can be calculated from the latent heat, pressure, and temperature, which latter have all been determined by Regnault.

The next question concerns the constancy of volume of the steam in

the cylinder, as an error will be introduced if the volume is not constant throughout the test.

In the first place, the volume of the cylinder may vary owing to expansion by increase of temperature—this may be calculated and allowed for. Increase of pressure may cause a variation of volume due to distortion of the cylinder, but does not seem at all likely, as the cylinder will be practically under an equilibrium of pressure. There may also be a variation in the volume of the pressure-gauge tube, and the motion of the diaphragm will also cause a variation which may be calculated and allowances made.

The volume occupied by the suspended water will be so small that it may be neglected. The next question is: Will the temperature of the steam in the jacket and tubes be distributed throughout the mass of the sample steam in the cylinder? There should be no doubt of this if the tubes are put sufficiently close together, and if care be taken that all surfaces exposed to the steam being tested are properly jacketed.

Leakage would be rendered impossible by brazing all joints exposed to pressure from the steam in the cylinder. The inlet and outlet valves H and G to the cylinder might present some difficulties, and in order to minimise these it will be seen that they are both so arranged that during the time of testing (the valve J being then open and the drain cock shut) the tendency to leak, which should depend upon the difference of pressure on each side of the valve, will be practically *nil*.

Probably the greatest difficulty will be the correct determination of the time when all the water in the sample is evaporated, and this will depend upon the efficiency of the diaphragm F in indicating small differences of pressure. The diaphragm can, however, be tested beforehand by subjecting each side to pressure by means of a column of mercury, noting what difference of pressure is required to break the electric circuit.

An error may be introduced, by the presence of air or vapours other than steam, in the sample. In all probability, however, if air were present it would be in exceedingly minute quantity and not sufficient to materially affect the result.

The apparatus may be applied to the receivers of an engine as well as to the steam pipe, and also to the exhaust as it leaves the low pressure cylinder, by which means our knowledge of what goes on in the cylinders would be vastly increased.

In conclusion, the writer wishes to again emphasize the value of exhaustive trials on marine engines and boilers, so that some answer may be given to the following questions:—

Is the economy of the triple expansion engine due to high pressure alone, or due to lessened initial condensation in the cylinders owing to a diminished range of temperature? If so, why do trials show that the initial condensation in the high pressure cylinder of the triple expansion engine is just as much and sometimes more than the condensation in the high pressure cylinder of the compound engine?

Is there not reason to believe that the ordinary marine boiler supplies steam containing a hitherto unsuspected amount of water, thus accounting for the apparently large amount of condensation in the cylinder? Does the presence of water impair, *per se*, the efficiency of steam?

Is the amount of priming affected by the boiler pressure? Are steam jackets of any advantage to a marine engine, and if so, to which cylinder should they be applied?

The discussion was adjourned, and the meeting dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

NINTH SESSION, 1892-93.

PROCEEDINGS.

SIXTH GENERAL MEETING OF THE SESSION, HELD IN THE PHYSICAL LECTURE HALL OF THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-UPON-TYNE, ON TUESDAY, FEBRUARY 21ST, 1893.

J. R. FOTHERGILL, ESQ., VICE-PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting, held in Newcastle, on January 30th, which were approved by the members present, and signed by the Vice-President.

The ballot for new members having being taken, the Vice-President appointed Prof. Weighton and Mr. Alex. Taylor to examine the voting papers, and the following gentlemen were declared elected:—

MEMBERS.

Drake, William Edward, Engineer, 7, Rodwell Terrace, Weymouth

Fowell, Ridley, Engineer Surveyor, Lloyd's Register of Shipping, Dock Offices, West Hartlepool.

Gross, Felix, Assistant Manager, c/o Messrs. John Brown & Co., Atlas Works, Sheffield.

Johnson, Alexander, Engineer, 12, Wandsworth Road, Heaton, Newcastle-on-Tyne.

Walter, Max, Shipbuilder, 120B, Smidtstr, Bremerhaven.

Walker, Henry, Electrical Engineer, 11, Oxford Terrace, Gateshead-on-Tyne.

MEMBER (LATE GRADUATE).

Dixon, John Rochester, Engineer, 79, Osborne Road, Newcastle-on-Tyne.

ASSOCIATE.

Weatherall, Henry, Accountant, 27, Alderson Street, West Hartlepool.

ACCIDENT TO THE PRESIDENT.

The VICE-PRESIDENT said he deeply regretted that they had not their President (Mr. Robt. Thompson) with them that night, and he felt sure he expressed the feeling of the meeting in saying that their full and deep sympathy was with their President in his affliction. No doubt they had all heard of the accident and the very narrow escape he had had. He (the Vice-President) was pleased to say he had had a letter from the President saying he had greatly improved in health, but that it would be some time before he would be able to attend to business. He had been ordered to take a rest and change of air, but they hoped that by next meeting he might be able to be with them again.

THE CHICAGO EXHIBITION.

The VICE-PRESIDENT intimated the receipt of a letter from Mr. Dredge, who was editor of *Engineering*, and also the honorary president of the International Engineering Congress to be held in connection with the Chicago Exhibition. The letter had been sent to the Council, and stated that any member of the Institution desirous of reading a paper at the Congress should communicate with the writer (Mr. Dredge). If any gentleman was desirous of doing this at Chicago he (the Vice-President) had no doubt his paper would be duly honoured.

Mr. D. B. MORISON concluded his reply to the discussion on his paper on "Marine Boiler Furnaces" (see page 207).

The discussion on Mr. W. R. Cummins's paper, "On Apparatus for Determining the amount of Water suspended in Steam" was resumed.

Mr. L. NEWITT read a paper on "Ships' Electrical Fittings."

ADJOURNED DISCUSSION ON MR. W. R. CUMMINS'S PAPER "ON APPARATUS FOR DETERMINING THE AMOUNT OF WATER SUSPENDED IN STEAM."

The SECRETARY read the following

COMMUNICATION FROM MR. ALEX. H. W. KENNEDY TO MR. CUMMINS, AT DUNDEE:—

DEAR MR. CUMMINS,

Since writing you I have read your paper more carefully. I am afraid that the method you propose will not really determine priming. If it works rightly, surely all it can determine is the amount of water present in the steam. This is exactly the same determination as is made by Barrus's instrument and by the old method. But this is not necessarily priming, and may be enormously different from priming in certain cases. I have found an engine to be very wet at the indicators when the boilers were not priming measurably at all, simply because of condensation in pipes, and, I think (under some circumstances), of condensation from the roof of the boiler. This is a matter which I have brought up in discussion once or twice, and I think the distinction between real priming and water in steam is most important. For the former, the boiler is responsible directly, but the latter is a totally different affair.

Also are you quite sure of your facts as stated on page 239, viz., "that superheated steam has a lower pressure than saturated steam of the same temperature?" This is quite new to me, and I should be very glad indeed to know on what experimental basis it rests. I do not deny it, simply because I have never heard it suggested before, and it is probably based on some researches which have not yet come to my knowledge. Your remarks about the difficulty of sampling the water in the salt test are perfectly justified, and of course raise the real objection to this method. Barrus's method appears to me to be based on some assumptions about superheated steam which are not founded on anything much better than text-book statements. His method also is open to the very great objection that whereas the quantity looked for is a very small one, an initial correction has to be made for the effect of radiation, etc., which is a very big one, and it seemed to me that the method was

altogether untrustworthy, except as a general indication of whether or not there was considerable priming. The old "barrel" method I have carried out. It is liable to the same objection as yours, viz., that it does not distinguish priming from other water, and it requires the most minute accuracy in weighing and the greatest possible care to get anything like a reasonable result. As the priming is virtually determined by an extremely small difference, an error of even a half per cent. in the original weighings may be 50 or 100 per cent. in terms of the small quantity to be looked for. It is for these reasons that I have myself adopted the salt method. The figures that one gets are very easily obtained with perfect accuracy, and it actually represents the thing looked for. Its drawback is, of course, the uncertainty as to how far either your water or steam are accurately sampled, and I quite agree with you that this is a very serious drawback. If I knew any other method which had smaller drawbacks I would gladly adopt it. Your own method, by the way, is, I think, open to a similar objection—that the steam getting into the condenser, a complicated space full of corners and angles, is hardly likely to be a fair sample of the actual steam rushing along a straight pipe, and particularly so in the matter of the amount of water it contains.

Yours faithfully,

ALEX. H. W. KENNEDY.

Mr. J. JENNINGS CAMPBELL said he thought they were much indebted to Mr. Cummins for his interesting paper, bringing before them the subject of the determination of the quantity of water suspended in the steam supplied to engines. The recent trials of the "Research" Committee of the Institution of Mechanical Engineers unmistakably showed that they had to deal with very large quantities of water contained in such steam; and any apparatus which would enable them to measure correctly the relative proportions of water and steam must be of great value. Before discussing the matter of the paper, he would like, if in order, just to say, in regard to a remark made by Mr. Kennedy as to Mr. Cummins's apparatus, that it was more constituted for determining the water present than priming, that as he (Mr. Campbell) understood from the paper, it was just the determination of water that Mr. Cummins claimed, because, in another portion of his paper, he suggested that the apparatus should be applied to different portions of the steam-pipe or engines, so as to take steam at any point at which they wished to determine the quantity of water, and not simply at the indicator cocks. Then, in regard to

Professor Kennedy's remark about Mr. Cummins's statement, relative to the pressure of saturated and superheated steam, it rather occurred to him that Mr. Kennedy had been a little bit confused by the form in which Mr. Cummins had made his remark, in stating that saturated steam had a higher pressure than superheated steam. It was generally understood that when steam had once arrived at a dry saturated condition, they might go on heating it to a very considerable extent, increasing its temperature without sensibly increasing its pressure. It was just another way of stating the same thing. With regard to the author's description of the two actions producing priming, he could not set himself up as any authority on the subject, but he must confess that he failed to entirely follow him. He did not see how a bubble of steam rising through the body of water in a boiler was likely to carry water up with it, nor how a particle of water could receive only sufficient heat to evaporate part of it, and then that the remainder should be carried off with the steam. Did he understand Mr. Cummins to mean that when such a particle had been partially turned into steam the remainder was carried up in an envelope of steam, so to speak? Was this also what the author meant when he calculated that if a particle of water, originally containing 5 per cent. of salt, received only sufficient heat to turn three-fourths of it into steam, the resulting steam would contain one-fourth of that salt? He had generally understood that when any saline solution was evaporated, only the solvent was turned into steam or vapour, and the salt was left behind, rendering the remainder of the solution stronger—up to saturation point—and then being deposited either in the form of crystals or powder. In such a case no salt would be carried away into the steam space except by the mechanical action at the surface of the water referred to above. With regard to the ingenious apparatus suggested by Mr. Cummins for determining the amount of water present in the steam to be tested, he presumed he was right in understanding that whether the hotter steam to evaporate the contained water, were taken from the boiler or pumped in, in either case the pressure and temperature in the jacket was to be gradually increased until the water in the steam under test had all been evaporated. It was evident that it would be necessary to do this sufficiently slowly to secure the pressure and temperature in the cylinder being always equal to that in the jacket, until the saturation point was reached; otherwise the steel diaphragm would be actuated too soon. Here, he would imagine, would lie the chief difficulty, as heat could hardly be transmitted through the best conductor instantaneously, especially when the difference of temperature on the two sides was very

small, and the result would be that there would all along be some difference of temperature and pressure between the jacket and the cylinder, and it would, he should imagine, be very difficult to ascertain this with sufficient accuracy to regulate the force required to actuate the steel diaphragm at the right moment. Should he be mistaken in his views on this point, and it were really necessary to have a very sensitive device for indicating the slightest difference of pressure in the two spaces, he would suggest that an inverted syphon or U-pipe containing mercury would be more sensitive than the steel disc. The upper ends of this pipe would be stopped with plugs of electrically insulating material, through which would pass wires; one reaching down nearly to the bottom of the U-pipe and well into the mercury; and the other having a sharp point set just in, or out of, contact with the surface of mercury in the other leg, according as it was desired to make or break contact. This latter wire must be capable of very delicate adjustment by a fine threaded screw. One leg of the U-pipe would be in communication with the cylinder and one with the jacket; and means would be devised to prevent the mercury being blown out of the tube into the cylinder. Referring to the questions at the end of Mr. Cummins's paper, he would rather like to say something, but he had, he thought, occupied his fair share of time at any rate for the present, and would leave them to be dealt with by other speakers. Mr. Cummins had given them a most interesting and important subject to deal with, and he hoped they might have a good discussion upon it.

The discussion was adjourned, and it was left for Mr. Cummins to reply in writing.

The VICE-PRESIDENT said he thought they should pass a vote of thanks to Mr. Cummins for his very able paper. It was of great value, as had been shown by the trials made for the Institution of Mining Engineers. He thought he might take it as the unanimous wish of all that a hearty vote of thanks be accorded to Mr. Cummins for his valuable paper.

The vote was accorded by acclamation.

SHIPS' ELECTRICAL FITTINGS FOR LIGHTING, SIGNALLING, TELEGRAPHING, AND FOR MOTIVE POWER, ILLUSTRATED BY ACTUAL APPLIANCES.

By L. NEWITT, A.I.E.E.

[Read before the Institution in Newcastle-upon-Tyne, On Tuesday, February 21st, 1893.]

On board men-of-war and mercantile ships electricity has become an absolute necessity, and no steamship of any considerable size is now complete without its electrical equipments.

Two properties of the electric current are generally made use of:—(1st) that of causing heat where a great resistance is placed in the circuit; and (2nd) that of giving magnetic properties to any conductor through which it passes.

The most familiar example of the first property, viz., that of causing heat, is seen in electric lighting and also in electric firing of guns. In both cases the heat and light generated at the lamp and fuze are due to a resistance being interposed in the circuit of wires. This is clearly illustrated (Plate XLII.) in the following experiment:—

Standing on the table are two copper rods about 6 inches apart. To each of these is attached a cable, which is connected with some accumulators, and the copper rods at their upper extremities are metallically connected by a piece of fine platinum wire. On passing a current of electricity through the circuit it will be seen that the copper rods keep quite cool while the platinum wire becomes first red-hot, and then burns up. In this case the copper rods offer practically no resistance to the electricity, but immediately the current attempts to pass the fine platinum bridge a great resistance is offered and heat is generated.

This property of the electric current is made use of in the firing of all modern guns, and specimens of the actual fuzes and primers can be seen on the table.

In the case of the electric lamp the resistance is found inside the lamp, and when a rush of current from the battery or generator passes over the fine carbon or platinum bridge inside the lamp a considerable

amount of heat is set up, and consequently a light is obtained. The cables carrying this current of electricity to the lamps, being much better conductors, remain perfectly cool. The lighting in this lecture hall clearly demonstrates this point.

Among other applications of the heating effect of the electric current to be brought under notice is that applied to warming rooms or cabins and cooking food. Cabins up to the present time have been heated either by stoves or steam pipes. Stoves and their attachments, are very inconvenient on board a rolling ship, as ashes and smoke cause great discomfort. Steam pipes are also objectionable in that they are costly to fit, leaky, and the stove pipes dangerous, as explosions sometimes take place when stoppages occur, owing to corrosion of piping and from frost. Whereas if electricity be used all the above inconveniences are avoided, and a perfectly dry heat is obtained without draughts, which are a necessary evil whenever fires are employed. The question of cost of electrical heating compares very favourably with other systems.

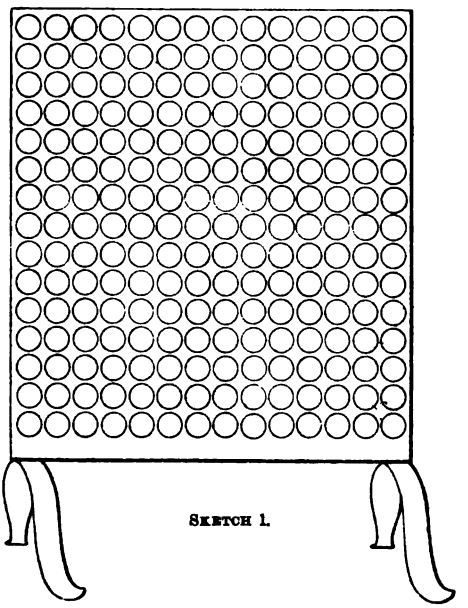
For cooking, electricity is a great success, and it is possible before long it will be recognised as a necessity on board ships. The fire, as at present used, is the cause of the greater part of the offensive smell which arises from cooking and renders this part of the ship uninhabitable, and in hot climates makes the duties of a cook almost unbearable. If electricity is used, these evils are to a great extent overcome, as the heat is quite local and ashes and soot will become an unknown delicacy in the soup dish.

One other advantage of electrical heating and cooking is that all fires are dispensed with about the ship except in the ship's boilers, where they are a necessity and the surroundings are adapted to them.

To engineers who have not closely followed the progress of electricity during the last three or four years the foregoing statements will appear to require some proof, and for this purpose a special heating apparatus for cabins, and a cooking appliance, has been placed on the table for trial and examination.

The heating appliance (Sketch 1) can be easily demonstrated by putting on the current and holding a thermometer over it. In a few seconds it will be found that the temperature about the electrical heater has risen several degrees. To give a clearer idea as to the construction of these heaters the instrument being used for this experiment is left open so that the spiral wires through which the current passes can be seen. The instrument has been used to warm a room for about two years, and has given great satisfaction. If the room gets too warm the current can be switched off and the heat at once ceases. If the heat is again required it is only necessary to turn on the current, and as will be

seen by experiment, heat arises almost immediately. As to the cooking appliance, experiments have been made by reliable electricians, who state that a pint of water can be boiled in 10 minutes and a steak cooked in 12 minutes with a current of 3 ampères at 100 volts, or about $\frac{2}{5}$th E.H.P. In addition to this there is on the table for examination a large and small kettle and a specially arranged cooking apparatus as illustrated on Plate XLIII.



SKETCH 1.

The subject of electric lighting has been so fully discussed at the meetings of this Institution on previous occasions that it is only proposed now to deal with a few of its latest applications.

A point of some importance with reference to the lighting of engine rooms and stokeholds comes under notice in dealing with this subject.

Until recently it was the practice to fit a large number of small lights in these compartments. It is now found that one-tenth of this number of lamps, or less, in each of these compartments, of a high candle-power, say about 200, placed in carefully-selected positions, are sufficient for ordinary running. This not only cheapens the first cost of electric lighting on a ship, but also is less trouble to keep in good working order, and at the same time improves the general effect, all of which are important details. A guarded fitting complete with lamp, as fitted, is on the table, and gives an idea of its value.

Electric signalling from ship to ship has been recently very much developed.

A flash lamp (Plate XLIV.), the invention of Commander Scott, is placed on the table and is arranged so that a powerful electric lamp can be exposed to view or entirely shut off, when used by a Morse telegraphist, with great rapidity. This lamp is to be carried at the top of the masts of ships of war, and if a code of signals is previously arranged messages are very quickly sent. Thus, for example, a long exposure of the light, and 3 short and 1 long exposures may be arranged to mean that the surrounding ships are to "weigh anchor and steam full speed."

Formerly it was customary to switch the lamp on and off, but seeing the length of time it takes the filament in the lamp to cool, the signals would only be transmitted very slowly. The great value of rapidity can be seen when long messages have to be transmitted. In most cases for these instruments the Morse telegraphic lettering is adopted.

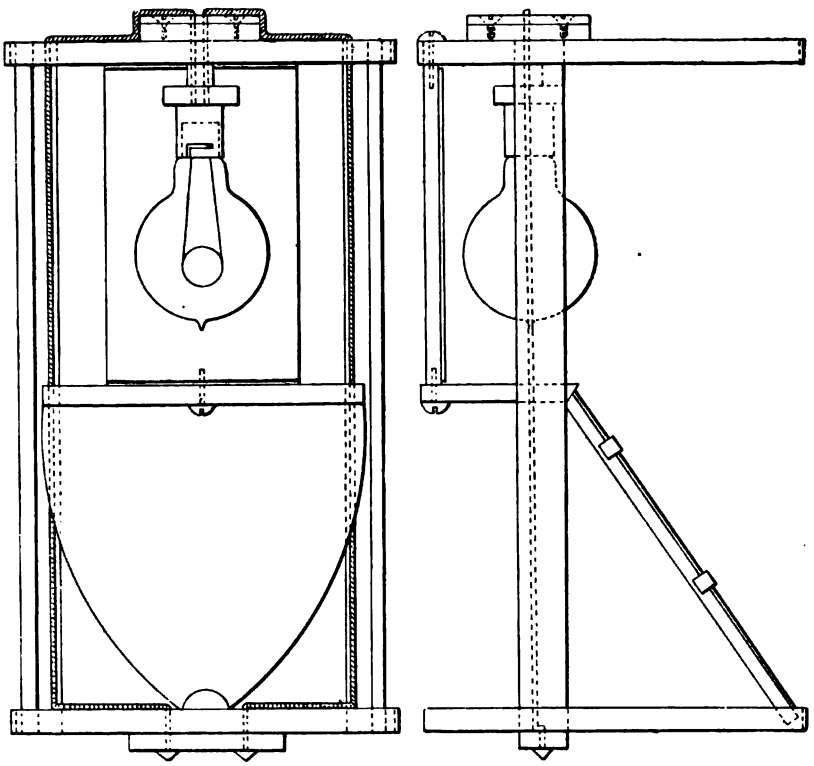
It may be of interest to some present to see an exact type of a projector (Plate XLV.), which has been fitted up to show its method of working and its effects. It consists of an arc lamp, the carbons of which are manipulated by hand, and covered by a hood. A mirror is fitted at the back of the lamp to project the light forward in a powerful beam, which penetrates to a considerable distance. A lamp made upon this design, taking 100 ampères and 80 volts, gives a light of 20,000 to 25,000 candles, and can clearly illuminate an object 4 miles distant in a clear atmosphere.

Another of the important developments of electric lighting is seen in this model of a gun, where the light is introduced into the sights for use at night. These night sights consist of two small fittings, which are easily attached to the heads of the ordinary day sights. A minute point or line of light is obtained at each sight by permitting the rays proceeding from an electric lamp to pass through a small glass lens on the foresight, and to illuminate the cross-bar of the rear sight.

By means of an adjustable resistance the light can be modulated so as to suit the degree of darkness of the night, or to suit the eye of the observer. It is found in practice that the smallest quantity of light compatible with distinguishing the sight is best, as the eye is not dazzled thereby. By means of these night sights an alignment can be taken up with unusual accuracy and rapidity, and the sights can be applied to all natures of guns, large and small.

It is unnecessary to point out how great is the advantage of being able to direct an accurate fire at night, in presence of the greatly developed power of torpedo and other nocturnal operations.

The lamp of the rear sight can be removed for the purpose of seeing the range scale on the sight bars while adjusting the sights. Plate XLVI. shows the application of the night sights to a 6 inch gun on a centre pivot mounting. The arrangement is similar in principle for all guns.



SKETCH 2.

Another application is that of a lamp with an inclined reflector (Sketch 2) to pass up the bore of a gun or other tube to show the condition of the surface. As the lamp is moved along, the reflector distinctly reveals any flaws which may exist; and it may be turned upside down or to either side without there being any flame to dull the surface under examination. The light is so clear and so close to its work that the minutest speck is revealed. Indeed, even the eye at a few feet distance cannot see all that the mirror will reveal without the aid of an opera glass. This could of course be used, if desired, for the examination of boiler tubes, steam pipes, and the like.

For purposes where it is not possible to have connections on to a dynamo for giving the required current, combined portable electric lamps

and batteries have been designed. The instrument on the table is similar to a lamp used at present on the Metropolitan Railway for reading purposes, and is the invention of Messrs. Davis & Tourtel. There are many modifications of this lamp, each adapted to different uses. A battery weighing from 3 to 5 lbs. will run an electric lamp of 1 candle-power for about 8 hours.

The aid of electricity is also being called in to help the surgeon. He not only uses a heated platinum wire for cauterising, but one of the most recent facts is that instead of using an ordinary hot poultice an electric lamp is now lighted, cased in flannel or other necessary covering, and used whenever a patient requires heat. The advantages of the above can be clearly seen at a glance.

To pass on to the second property of the electric current, viz., that of imparting magnetic power to any conductor through which it passes.

The most familiar example of this is the electric bell, with which you are all familiar, and in the mechanism of which there is a little piece of soft iron upon which a coil of fine wire is wound. The apparatus is so arranged that on the bell-push being pressed down the circuit is closed and the current passes through the coil of wire and converts the piece of iron into a magnet to pull the hammer and make it strike the bell. But in the act of striking it breaks the circuit and rebounds, only to be caught back by an automatically re-made current, and the great number of times that the hammer strikes the bell during the time that your finger is on the bell-push is the number of times that the little piece of iron has been converted into a magnet and demagnetised.

Another application, which is not so well-known, is that of electrical indicators on board ship for such purposes as indicating the positions of the helm, and transmitting from the bridge the commands of the captain and also to the bridge the replies.

There are many reliable instruments at present made, the one exhibited is the invention of Capt. Lloyd, which happens to be arranged as a distance indicator for gun ranges. It consists of a transmitter (see Fig. 1, Plate XLVII.) and a receiver (see Fig. 2, Plate XLVII.). The transmitter is placed at the point from which the orders are to be sent, and the receiver is placed where those orders have to be executed. As at present fitted in this lecture hall it will be noticed that a second receiving instrument is placed near to the transmitter. This is so arranged that those sending the signal may see by the reply that their message has been correctly received, which is done also with many of the mechanical instruments now in use. Thus it will be seen that instruments of this

class can be adapted to a wide range of purposes of telegraph and indication on board ship—a system which saves those in charge much trouble, seeing that it is not necessary to have a totally different description of instrument for each purpose.

Up to the present time primary or secondary batteries have generally been used to give the current necessary for working electric telegraph instruments, and if a failure ever occurs it invariably is traced to the battery. To overcome this point a magnetic switch has been designed, which is placed in the circuits of the dynamo used for electric lighting, and is so arranged that as soon as the dynamo is working the switch automatically throws in the telegraph circuit, which, as long as the dynamo is running, will be worked by the dynamo current, a resistance being placed in the telegraph circuit to allow only about one ampère to pass through the telegraph instruments.

A dynamo is usually kept running when all large ships are in motion, so that these instruments are practically always worked by the dynamo current, but in case the dynamos should not be running the magnetic switch automatically cuts out the dynamo circuit, and throws in a battery which is kept connected up ready for use.

The addition of this automatic switch will do much to avoid any possibility of breakdowns in telegraphs.

Plate XLVIII. illustrates the instruments and circuits of a complete set of electric telegraphs as fitted on board a battleship by Messrs. Elliott Bros.

The great points of importance of electric telegraphs and indicators over mechanical appliances may be briefly enumerated as follows:—

1. The wires required for electric telegraphs are fixed to the ship and no movement is required, whereas with mechanical telegraphs the wires used are constantly moving, thus they are liable to wear out more rapidly, to get stuck, and to get off their pulleys owing to vibration, a blow, or stretching.
2. As the electrical telegraph wires are fixed all bulkheads can be made water-tight, but with mechanical systems the moving wires must have a free passage through bulkheads, thus impairing the water-tightness of the division, and by this means destroying to a certain extent its value as a bulkhead.
3. As it does not matter whether the electrical wires expand or contract from excessive heat or cold it has the advantage over the mechanical wires, which are constantly giving trouble owing to expansion and contraction.
4. The mechanical system is more costly and troublesome to fit.

The transmitting and receiving instruments of both mechanical and electrical systems are satisfactory, but seeing that so many points are in favour of the electrical system we may hope that electricity will soon be universally employed for these purposes.

Before passing on to the question of motors another method of communication on board a ship should be mentioned, viz., the telephone. At first sight it does not appear to be of much use, but after much experience and care a telephone has been introduced which is less costly, and, in some cases, more efficient than ordinary voice pipes.

In a trial at the Elswick shipyard, in noisy workshops, these telephones were found to be more distinct than the ordinary 2 inch voice pipes over a distance of 80 yards.

A set of telephones, fitted by Messrs. Mills & Sons, has been put up into this room for trial and examination. On whispering into one of these instruments the makers find that it can be clearly heard when the transmitting and receiving instruments are placed many hundred miles apart. These instruments, if no accident happens, will work without repairs for two or three years.

The question of motors has of late been occupying the minds of electricians in regard to their application to uses on board ships. There are many points in favour of their adoption for some classes of work where small engines are now employed, especially where high speed is permissible, such as in the case of pumping, driving of fans, working of hoists, fire engines, and the like.

A few advantages which the motor possesses are :—

1. The power to do work is more easily carried through the ship, seeing that it only requires a fixed cable instead of a steam or water pressure pipe.
2. There is also less loss upon the road.
3. The bulkheads are not damaged by the cable passing through them to such an extent as when pipes are used.
4. No appreciable heat is given off by the wires, whereas if steam is used, the compartments through which it passes may sometimes be overheated, and leakage from the pipes may also do much damage to any stores or cargo which happen to be in the compartments through which the pipes pass.
5. The very small space occupied by the wires as compared with steam piping.
6. The cost of cable and installation is less than that of piping.

For ventilating fans it is possible to make use of the high speed

attained in motors without any intervening gear, or in a handing room of a magazine for bollards and small hoists, where steam is objected to.

It is under such circumstances that motors have been most successfully employed. They may with equal success be applied to centrifugal pumps and any other machinery of high speed. It is quite possible that in the near future a slow speed motor will be invented specially to meet slow speed requirements, and then a further change will probably take place in many auxiliary engines now using steam and water. At present if it be required to train or elevate a gun by motors the amount of gearing necessary to reduce the speed of the motor, which to work efficiently must run at from 500 to 600 revolutions per minute, absorbs a proportion of the power, besides adding considerably to weight and cost of machinery.

Messrs. Scott & Mountain have recently gone thoroughly into such questions, and their endeavours have met with very marked success. In one case, which may be taken as a sample of many others, the motor worked at 720 revolutions per minute through a worm, driving a worm shaft at 30 revolutions per minute; the loss of power by worm friction is said by the makers to be less than 15 per cent., while giving off 12 horse-power. The small working model on the table illustrates this system, which is applied to two capstans now being built for the Dunston Flour Mills. A diagram of this worm-gearing is shown on Plate XLIX.

Messrs. Siemen Brothers have also arranged another method of gearing by which the speed of a motor can be reduced, and by this means a winch or capstan can be successfully worked. The winch is illustrated on Plate L., and is capable of lifting 5½ tons at the rate of 100 feet per minute with an expenditure of 35,000 watts. It is complete upon a cast iron baseplate, and is driven in either direction by a motor placed in a water-tight metal cover. The motor is of the horseshoe type, with armature above the electro-magnets—the baseplate of the winch forming in part the yoke-piece. The controlling lever is to the right of the operator, and actuates an electrical switch, which is enclosed in a water-tight box fixed to the frame of the winch. When the lever is in middle position no current passes through the motor, but by moving it in the one direction or the other, that is, away from or towards the attendant, the motor revolves in corresponding directions, its speed being regulated by the angle through which the lever is turned.

The motor is geared to the winch by means of helical gearing, and a quick motion is provided for light work, to secure which the lever in

the centre of the winch is provided; so that by moving it to the right or left the necessary alteration is made in the gearing of the winch. A foot-lever is placed in a convenient position, and is in connection with the brake on the barrel shaft in the usual manner.

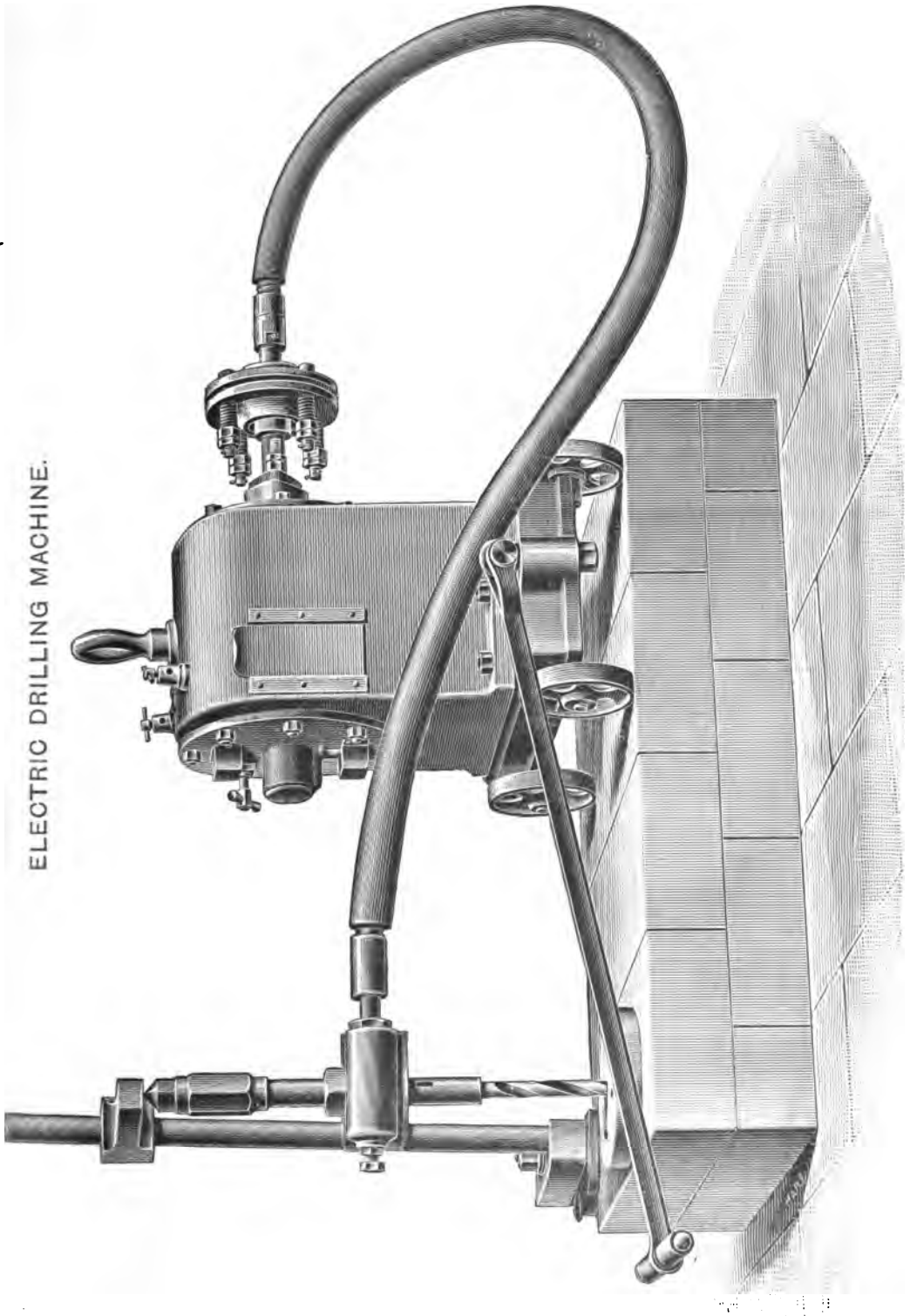
In some cases for cargo lifting electric motors might with advantage be used, as will be seen by watching the small working model of a bollard.

The small model fans now working give a clear idea of their capabilities and the ease with which they can be worked at a distance from the source of their power. For example, one of the motors now running on the table is driven by a supply of current supplied by the Newcastle and District Electric Supply Company, whose central station is one mile distant from the motor.

In addition to the above applications, the motor has been most successfully adapted to give power for drilling purposes on board ships. One of the latest examples of this is seen in the electric drill on the table.

From the illustration on page 259, it will be noted that the drilling machine consists of an electric motor of special type, *i.e.*, the motor is entirely encased in a cast iron box; the commutator brushes and all working parts being thoroughly protected from any possibility of mechanical injury either from anything falling upon the motor or from damp. At the end of the motor spindle it will be noted that a slipping coupling has been provided, which prevents any possibility of the motor being stopped through too much pressure being put upon the drill, and damage from an excessive current passing through the armature. The connection between the motor and the drilling head is made with a flexible shaft, which can be of any length suitable for the particular class of work that the drill is intended for. As a matter of fact, a shaft for a drill for drilling 1 inch holes is $1\frac{1}{4}$ inches diameter; this shaft is protected by a leather covering, and it can be twisted to any angle required. The drilling head consists of a gun-metal box in which there is a worm and worm-wheel, the worm being attached to the flexible shaft and the worm-wheel to the drill socket; a hand-feed is provided enabling the drill to be set up in the same way that a ratchet brace is fitted, but, if desired, a hand-wheel can be fitted for this purpose. Of course the speed of the drill can be regulated by suitably arranging the worm gear, but in addition to this it is an easy matter to regulate the speed of the motor by a special switch which has been designed for this purpose.

It will be seen that a portable arrangement of this kind will be most convenient in shipbuilding yards and erecting shops for rimering out



ELECTRIC DRILLING MACHINE.

holes, and in fact for drilling purposes generally. It is only necessary to put up an ordinary drill post with a longer arm and the drill can be moved from hole to hole with very little loss of time.

Of course the design of the drill head can be altered, and attached to a swivel arm, similar to a radial drilling machine—this is a modification only in construction.

In oil ships, where it is very necessary that the holes should be perfectly fair, it is customary at the present time to rimer these holes by hand, which is a long and tedious operation, and the writer is satisfied that a drilling machine of this sort introduced into a shipyard, where there is much of this class of work done, would effect a very considerable economy.

The same class of drill would save a considerable amount of time and expense for ordinary electric light work on board ships where there are many holes which have to be drilled by hand.

With all these appliances to be worked electrically on board ship, the next point to be considered is the power for driving them. There are two courses open:—1st. The engines and dynamos which are used for running the electric light may also be employed to give power to a large number of auxiliary machines. 2nd. Primary or secondary batteries may be used, but it is found, however, to be advisable to use current generated by the dynamo, and not use batteries except in case of breakdown.

There are now many engines and dynamos in the market, each in turn claiming some advantage over its fellows.

Amongst others, one which has given great satisfaction all round, is a Siemens-Belliss combination, illustrated on Plate LI. The whole plant is designed upon thoroughly practical ideas, and is an excellent machine for efficiency and long runs.

Plate LII. illustrates a special feature of the engines, viz., the valve gear. It will be seen that the high and low pressure slide valves are of the piston type, placed in line with each other, working in the same valve chamber, and driven by the same eccentric.

The lubrication, always an important point in engines having to make long continuous runs at a high rate of speed, has been carefully considered in these machines. The water consumption per E.H.P. per hour is found to be about 34 lbs. of water converted into steam at 100 lbs. working pressure.

These machines run at a speed of about 320 revolutions per minute, and great numbers of them have been fitted into cruisers, but for the

merchant service it is an open question whether the speeds might not be increased with advantage.

By enclosing these engines Messrs. Belliss have no difficulty in running their machines up to more than 600 revolutions per minute, special arrangements being made to force oil through the bearings and thus keep them free from overheating.

Several other makers have also devoted some time to the design of dynamos and engines, one of which is illustrated on Plate LIII., made by Messrs. Scott & Mountain. Amongst these also are the excellent machines of Messrs. C. A. Parsons & Co., of Heaton, illustrated on Plate LIV. They have lately been very much improved, both in design, efficiency in running, and steam consumption. When economy of first cost, weight, and space are of great importance there is no rival to these combined engines and dynamos. Its electric governor is perhaps the most perfect in the market.

Now comes the important question as to who shall look after these machines, to keep them in working order, and to repair them when they go wrong. It is not at all difficult to meet this point. At the present time there are many young engineers who have attended electrical classes, or have been through a proper electrical training college, besides having qualified themselves as marine engineers. One engineer with this knowledge would take his turn with the other engineers, and by this means the staff to navigate a ship would not be increased. As soon as sea-going engineers find that preference will be given to those with an electrical knowledge, and the Board of Trade make it essential for all marine engineers in future examinations to pass in electrical subjects, the difficulty disappears.

The shipbuilders and engineers of this district are well able to take the lead in this subject (as they so generally do in other matters); and by judiciously introducing electrical mechanism well-devised, cheaply constructed, and economically worked, they may bring more orders to the North-East Coast.

In closing, the writer would take this opportunity of expressing his indebtedness to those who have so kindly assisted, by the loan of apparatus and the supply of power for the work of this evening, and by the loan of illustrations for this paper.

The signalling, telegraphs, night sights, fuses, tube examiners, and connections by Messrs. Sir W. G. Armstrong, Mitchell & Co.; the accumulators, diagrams, motors, and drills by Messrs. Scott & Mountain; the projector, diagrams, and motor by Messrs. C. A. Parsons & Co.; the

motor and fan, heaters, and power by the Newcastle and District Electric Lighting Co.; the valuable information and diagrams supplied by Messrs. Belliss & Co.; Messrs. Siemens for diagram of winch; the electric grill from the patentee, Mr. Andrew Wallace, Newcastle; Mr. Ryder, of the firm of Messrs. J. Mills & Sons, Newcastle, for the loan of telephones; Messrs. Elliott Brothers for diagram and information upon electric telegraphs; and Messrs. Crompton & Co. for the loan of heaters and information connected with them.

DISCUSSION.

The VICE-PRESIDENT observed that unfortunately there was no time that night to discuss fully this able, valuable, and interesting paper. They had only the use of the hall till ten o'clock. They had a few minutes left, and he would call upon Captain Lloyd to open the discussion.

Captain LLOYD said he had to thank them for this privilege and Mr. Newitt for an exceedingly interesting and instructive evening. It was rather hard to open a discussion on a lecture such as this, because Mr. Newitt had taken up so many subjects. He could easily have taken up all the time he had in describing one instrument, even the cooking instrument. Mr. Newitt had been obliged to go from one to another without giving them full details. He questioned whether Mr. Newitt was correct in saying that the heating of cabins and rooms could be as economically performed by electrical apparatus. He thought that was a point open to discussion. It was conveniently performed, no doubt, but he did not think for economy that it could compare with more direct methods. Then, with regard to lighting ships. Having spent twenty-one years in Her Majesty's Navy he could speak with some authority, and he did not think anything could be more appropriate than electric lighting. Gas was tried in one ship, the "Devastation," but it failed miserably. Up to the last few years sailors had to be content with candles, oil being prohibited as being too dangerous. The electric light came in and removed the gloom on board ship at nights. He (Capt. Lloyd) was in the first vessel fitted up with electricity, the "Inflexible." They first tried a very high tension current with the brush dynamo from which they got an electro-motive force of 850 volts, and tried to use a large number of Swan incandescent lamps in series. It was soon found that this was a mistaken way of doing it both from economical reasons and from danger. They had the misfortune to have one poor fellow killed

by taking too much current. Then with regard to the night sights, that was an interesting point on board ship. Experiments at Portsmouth showed they could make equally good practice at night as in the day time. Nothing in this direction could exceed such a result. With regard to the use of electric motors on board ship they were at a great disadvantage in having to reduce the speed of the motor, and there was also some difficulty in switching the current on at full speed. If they put too much current on to the motor at once they stood a very good chance of burning up the armature. While the motor was running it was, as it were, creating a reverse current and absorbing the power put into it. When they tried to use it for lifting ammunition or training guns he did not think its success was such as to supersede hydraulic power. This was a subject, however, that one could go on speaking about the whole night.

The discussion was adjourned to the April meeting at Sunderland.

THANKS TO THE COLLEGE AUTHORITIES.

Mr. D. B. Morison said they were there through the kindness of the Durham College of Science, the authorities of which had not only lent them the room to meet in, but supplied them with some of the current by which the experiments had been made. He had much pleasure in proposing a hearty vote of thanks.

The Vice-President was sure it was the unanimous wish of the meeting that a hearty vote of thanks be carried to the Durham College authorities for the use of the room.

The vote was carried by acclamation, and the meeting dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

NINTH SESSION, 1892-93.

PROCEEDINGS.

SEVENTH GENERAL MEETING OF THE SESSION, HELD IN THE ATHENÆUM, WEST HARTLEPOOL, ON SATURDAY EVENING, MARCH 18TH, 1893.

ROBERT THOMPSON, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting, held in Newcastle, on February 21st, 1893, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. G. W. Sivewright and H. Macoll to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Chapman, Harry Reynolds, Engineer Manager, Messrs. Clarke, Chapman & Co., Gateshead-on-Tyne.

Chisholm, Alexander, Ship Draughtsman, 2, Kent Villas, Kent Street, Jarrow-on-Tyne.

Edwards, James Harry, Shipbuilder, 15, The Lawes, South Shields.

Knaffl, Alvis, Engineer Surveyor, c/o Norddeutscher Lloyd, Bremerhaven.

Muir, Alfred Edward, Ship Draughtsman, 96, Roker Avenue, Monkwearmouth, Sunderland.

MEMBER (LATE GRADUATE).

Bruce, William, Ship Draughtsman, c/o Messrs. Harland & Wolff, Belfast.

ASSOCIATE.

Olsen, Hans Benedick, Shipowner, 70, Church Street, West Hartlepool.

GRADUATE.

Wakeham, John F., Ship Draughtsman, 50, De Grey Street, Newcastle-on-Tyne.

CONGRATULATING THE PRESIDENT ON HIS RECOVERY.

Mr. G. W. SIVEWRIGHT offered on behalf of the members present their hearty congratulations to the President upon his recovery. They were all very sorry to hear of his accident, and were indeed pleased to see him back again in the chair looking like his old self. He hoped his health would not suffer from what he had passed through.

The PRESIDENT said he very much regretted that the accident had prevented him from attending the meetings, but if there was any consolation in such a mishap it was in the amount of sympathy he had received from the Institution and those associated with it. He fully appreciated this kindly feeling, and was pleased he could be with them again. Some friends talking about the accident would say to him "Why didn't you do this?" and "Why didn't you do that?" His reply to them was, "I can tell the speed of a vessel, and there is a friend of mine can tell the speed of a bird going through the air; but I don't want any of you to know the speed with which you can be thrown out of a trap." The fact was one had scarcely time to think. He was thrown out like a shot from a gun, and did not remember anything until he was picked up. He was very thankful that his life had been spared. That was his first appearance at the Institution's meetings since the accident, and he was pleased that it was at Hartlepool, where he had such a successful opening at the beginning of his presidency.

GRADUATES' AWARDS.

The PRESIDENT announced the following awards to Graduates for the eighth session, 1891-92:—The first, to Mr. J. King, for paper on "Some Notes on the Propulsion of Paddle Steamers;" the second award was divided between Mr. E. Towers for his paper on "Hydraulics and Hydraulic Machinery," and Mr. R. L. Gaine for his paper on "Steamship Trials."

Mr. H. MACOLL wished to be allowed to say that those who had had to adjudicate upon these papers had had an exceedingly difficult experience. The papers were all so good, and one set was so near to another that it was difficult to place them properly. He hoped the Council would see its way to have either the papers or a summary of them placed in the printed Transactions of the Institution. It seemed to him that there would otherwise be an amount of valuable information lost.

The PRESIDENT said he could endorse Mr. Macoll's opinion. He had been present at the Graduates' meetings, and he was agreeably surprised at the amount of ability shown in the discussions. As they seemed to agree with what Mr. Macoll suggested, he would bring it before the next Council meeting and see if they could not have the best of the papers added to the Transactions.

The discussion on Mr. W. R. Cummins's paper "On Apparatus for Determining the Amount of Water Suspended in Steam" was resumed.

Mr. J. G. JORDAN read a paper on "Types and Proportions of Mercantile Steamers in relation to Cost, Carrying Capacity, and Speed," prepared by Mr. R. Marlborough and himself.

A discussion followed.

ADJOURNED DISCUSSION ON MR. W. R. CUMMINS'S PAPER "ON APPARATUS FOR DETERMINING THE AMOUNT OF WATER SUSPENDED IN STEAM."

Discussion being resumed on Mr. W. R. Cummins's paper "On Apparatus for Determining the Amount of Water Suspended in Steam," the SECRETARY said he had a short communication from Prof. Unwin. He was not a member of the Institution, but Mr. Cummins had written to him on the subject. He replied as follows:—

COMMUNICATION FROM PROF. W. C. UNWIN TO MR. W. R. CUMMINS.

DEAR MR. CUMMINS,

I have been very busy or I should have acknowledged your interesting paper on "Water Suspended in Steam." I have used the Barrus calorimeter, and I believe it to be extremely accurate and easy to use when the moisture is under 2 per cent. With a greater amount the separator must be used, and then the instrument is more troublesome, but I do not see any reason to think that accurate results cannot be obtained with it. I cannot understand Prof. Kennedy's doubt that superheated steam is lower in pressure than saturated steam of the same temperature. I think you must have misunderstood his meaning. I carried out all Fairbairn's experiments on the density of steam. You will find them in the *Transactions of the Royal Society* for 1860 and 1862. The second paper was on the "Law of Expansion of Superheated Steam." Fairbairn's second paper showed that the increase of pressure in superheated steam with rise of temperature was not sensibly different than that for air, the law being:—

$$\frac{P\,V}{P_1\,V_1} = \frac{459 + t}{459 + t_1},$$

for $V = V_1$

$$\frac{P}{P_1} = \frac{459 + t}{459 + t_1},$$

the temperature being Fahrenheit. This is a lower rate considerably of increase of pressure than for saturated steam. The Americans seem to have succeeded in determining the wetness of steam by an apparatus which is nothing more than a simple separator.

Truly yours,

W. C. UNWIN.

Mr. J. F. WALLIKER wished to add a few words, not from his own experience, but what he had heard from his friend and colleague, Mr. C. E. Stromeyer, of London, who, while at sea, had tried to estimate priming by measuring the quantity of salt water carried over with the steam. The conclusion he arrived at then was that in ordinary cases priming meant nothing else but *excessive condensation of steam.* He first of all tried to compare the density of the boiler water with that collected from the high pressure drain cock, but the salinometer not being sufficiently accurate, he tested the drain water chemically, by adding nitrate of silver, and found that no salt water had been carried over. Since then Mr. C. J. Wilson had applied a more delicate test, which consisted in adding a drop or two of a solution of yellow chromate of potash to the drain water, and then adding the nitrate of silver. This test was both accurate and easily carried out. This latter test had, he believed, been already mentioned in the *Transactions of Mechanical Engineers* for 1892. He would like to add that although Mr. Stromeyer had not appeared to be successful in gauging the *amount* of water carried over, still he thought it would be interesting to members to have his conclusions, and also those of Mr. Wilson, as to the absence of salty matters in the observations that they had been able to make.

MR. CUMMINS'S REPLY.

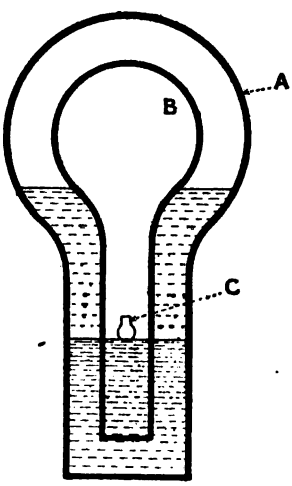
Mr. W. R. CUMMINS said—Prof. Kennedy points out that the apparatus designed by the writer is only suitable for determining the total amount of water present in the steam, and does not determine how much of this is due to priming, and how much to condensation from the roof of the boiler and in the pipes. This is quite true; but the writer's main object in designing the apparatus was to try and improve our knowledge of what takes place in the cylinder of the steam engine. To do this it is necessary to know the quantity of heat delivered to the cylinders, that is to say, the weight of steam and the weight of water mixed with it must be known; whether this water is due to priming or to condensation in pipes is a matter of indifference as regards the engine.

The condensation in a range of piping could be determined by the writer's apparatus by applying it to each end of the pipe. Our knowledge of condensation in steam pipes is due to experiments by Tredgold,

Burnat, and others, with steam of unknown quality and at rest within the pipe. It would be interesting to know whether condensation is affected by the motion of the steam in the pipe. The statement questioned by Prof. Kennedy that "superheated steam has a lower pressure than saturated steam of same temperature" appears to the writer to follow from the very definition of superheated steam, which is: "superheated steam has a higher temperature than saturated steam of the same pressure."

Take steam of 100 lbs. pressure absolute. If it be saturated its temperature will be 328 degs. Fah., and this temperature cannot be increased without increasing the pressure (provided it remains saturated). It is evident, however, that if there be no water present its temperature may be raised without increasing the pressure.

There is yet another proof of the above statement in the experiments carried out by Messrs. Unwin and Tate on the volume of saturated steam. The diagram will explain the method of carrying out the experiments.



A is a vessel containing mercury, with a layer of water on top of it. B is another vessel inside A, with a graduated stem, having its open end dipping into the mercury in A. A glass bubble C, containing a known weight of water, is introduced into B, and heat is then applied, evaporating the water in the glass bubble and also in A. As the evaporation proceeds the level of the mercury in A and B remains the same, but as soon as all the water in the glass bubble is evaporated the level in A

suddenly falls, showing that the pressure of the saturated steam in A is greater than the pressure of the steam in B.

Mr. Jennings Campbell does not see how a bubble of steam rising through a body of water will take up some water with it. It is a well-known fact that vapour passing through a liquid will take up some of it, as anybody can try for himself by blowing air through any volatile liquid. As regards the other action, the writer, perhaps, has not made his meaning clear, but Mr. Campbell puts it very aptly, viz., that the drop of water has been partially turned into steam and the remaining water carried up in an envelope of steam.

Mr. Campbell is quite right in saying that when a saline solution is heated the solvent only is turned into vapour, the salt remaining behind; this we know, but we do not know how and at what time the salt leaves the drop under consideration, and the salt test can only give true results on the assumption that the unevaporated water suspended in its envelope of steam has, at the moment it enters the steam space, the same percentage of salt as the body of the water it has left. Suppose, as before, an isolated particle of water at the temperature of evaporation, containing 5 per cent. of salt, and suppose three-fourths of it to be turned into steam, the remaining one-fourth of water, containing 5 per cent. of salt, passing along with the steam into the steam space. Then it is evident that the mixture of three-fourths steam (when condensed) and one-fourth water will contain only $1\frac{1}{4}$ per cent. of salt, and the calculation for the amount of priming is as follows :—

Salt in boiler water ... 5 per cent.
Salt in steam pipe ... $1\frac{1}{4}$ „

$$\frac{1\frac{1}{4} \times 100}{5} = 25 \text{ per cent. priming water.}$$

Now, as the particle of water becomes evaporated what happens to the salt? In the first place, the whole of the salt contained in the particle may become concentrated in the unevaporated water, the steam, in which the latter is suspended, preventing it from mixing with the body of water in the boiler. In this case the amount of priming indicated would be 100 per cent.

In the second place, the salt left by the steam might be taken up by the surrounding water, or else deposited on the heating surface and afterwards taken up by the water, in either case the unevaporated portion of the particle of water would have the same percentage of salt as the surrounding water in the boiler. In this case the priming indications would be correct.

In the third place, the suspended water may give up some or all of its salt preparatory to being turned into steam. In the case that all the salt is given up, the indications would give the priming as *nil*.

With regard to Mr. Campbell's remarks as to the necessity of increasing the pressure in the jacket very gradually, in order to prevent the diaphragm from being actuated too soon, the writer should have stated in the paper that the proposed method of working the apparatus, after the sample of steam is enclosed in the cylinder, should be as follows :—The contact screw is so arranged that when the pressure on each side of the diaphragm is equal, the circuit is closed and the bell ringing. The pressure in the jacket is then raised, say 5 lbs. It will be seen from the diagram that there is a strong plate immediately behind the diaphragm to prevent damage from over-pressure. If this increase of temperature does not evaporate all the contained water, the bell will ring again as soon as the temperatures in the cylinder and jacket have become equal, and then the pressure in the jacket may be increased another 5 lbs., and so on, until a point is reached when any increase of pressure in the jacket keeps the circuit open permanently, and any decrease keeps it closed.

With regard to Mr. Campbell's suggestion of the U-tube to replace the steel diaphragm, this would, no doubt, be suitable for land work, provided some means were adopted for preventing the mercury from being blown into the cylinder. It would, however, be of no use on board ship.

Prof. Unwin corroborates the writer's statement concerning the pressure of superheated and saturated steam.

With regard to Mr. Walliker's remarks on Messrs. Stromeyer and Wilson's experiments, the justness of their conclusions that water in the cylinders is due to nothing but condensation depends upon the accuracy of the salt test, which assumes that all the water coming away from the boiler has the same percentage of salt in solution as the water in the boiler. The writer is doubtful of this, and has pointed out his reasons in the paper. There is one other point which has not been touched on, viz., the possibility that bubbles of steam formed on the heating surfaces may become partly condensed by passing through a layer of comparatively cold water.

In many cases it is the custom to admit the feed into the boiler near the top of the combustion chambers, hence bubbles of steam rising from the heating surfaces would have to pass through this layer of cold water; some engineers even carry the end of the internal feed pipe into the steam space.

Supposing an extreme case, viz., that all the feed water was heated to boiling point by steam, and assuming temperature of feed 120 degs. Fah. and boiler pressure 160 lbs., then $363 - 120 = 243$ thermal units required to raise feed water to boiling point. Latent heat of steam of 160 lbs. pressure $= 858$ thermal units. $243 \times 100 \div 858 = 28$ per cent. of steam condensed, that is to say, if the feed water were taken through a system of pipes in the steam space, being raised in temperature thereby to boiling point, and the condensed steam remained suspended, the boiler would be priming to the extent of 28 per cent. of water, but the most delicate chemical test would not reveal any salt.

Of course the above assumed conditions could never obtain actually, but certainly some such action must take place, and especially when the feed is delivered near the water surface or into the steam space.

TYPES AND PROPORTIONS OF MERCANTILE STEAMERS IN RELATION TO COST, CARRYING CAPACITY, AND SPEED.

By J. G. JORDAN and R. MARLBOROUGH.

[Read before the Institution, in West Hartlepool, on Saturday, March 18th, 1893.]

Numerous papers dealing, more or less fully, with various types of mercantile steamers have already been read before this Institution, but they mainly discussed the more technical part of the subject, and there is now an opportunity of making comparisons between some of the prevalent types, which may perhaps be of more general interest.

The President (Mr. Robert Thompson), in his recent address, called special attention to the matter, and supplied a number of tables which have no doubt proved of considerable value to all interested in the shipbuilding industry. Although none of the tables then given are repeated in this paper, they have been used as a basis for the careful preparation of estimates which form the groundwork of the following comparisons of deadweight, cost, etc.

It is fitting that in Hartlepool, the home of the well-deck type of vessel, whose builders and owners long advocated, and at last succeeded in obtaining, a full recognition of the merits and sea-worthiness of this useful type, that one of its latest developments should receive a fair comparison with an older, and what appears at present to be an increasingly popular type. Although comparisons might have been made between all the types acknowledged by Lloyd's Register, the present purpose will be best served by restricting our comments to three, viz., partial awning, spar, and three-deck vessels. The comparison of cost, etc., is on a fairer basis between these three types, because, while the spar and three-deck vessels are fitted with complete 'tween-decks, the partial awning-deck class have them fitted for about two-thirds of the vessel's length.

Many forms of "improved" well-deck vessels are being built, all of which have merits more or less apparent, and although the partial awning-deck type has not always received the approval of the builders of the commercially successful well-deck, yet, up to a certain size, it is a close competitor with the spar-deck. Clearly there is a tendency to improve the old type of well-deck vessel out of existence for the larger size of ship, and towards the more general adoption of vessels having complete 'tween-decks.

The size of the well-deck type has increased yearly, so that now it is not so much a question of a type suitable for 1,500 or 2,000 tons deadweight, but for one capable of carrying at least 4,500 tons; and just as it has been found advisable to fit 'tween-decks forward when this size was approximated, so it will be that as dimensions further advance, and the disadvantages of a break in the deck-line are more and more realised, owners will be inclined to take a further step and fill in the after-well, leaving two complete decks with their continuity and better distribution of strength. Besides, now that a considerable freeboard allowance is made for the bridge erection in spar-deck vessels, and the additions to the scantling which it is found advisable to make to the larger class of partial awning-deck vessels, there is not the difference in deadweight nor in cost which formerly existed.

The writers are indebted to Mr. B. Martell, of Lloyd's Register, for the following table showing the number of steamers constructed for general cargo trades:—

TYPES OF CARGO VESSELS.

Year.	One and Two-deck.	Well-deck.	Awning-deck.	Partial Awning-deck.	Spar-deck.	Three-deck.	Total.
1875	41	39	3	—	6	40	129
1880	43	108	12	—	7	81	251
1885	43	64	5	1	20	21	154
1890	37	163	16	50	46	68	380
1891	88	139	10	58	50	71	416
1892	62	88	12	76	63	53	354

It may be of interest to note the variations of the number of vessels built of the three types under consideration, and this will be best shown as a percentage of the total for each year :—

PERCENTAGE RATIO.

Year.	Partial Awning-deck.	Spar-deck.	Three-deck.	Total.
1875	—	4·7	31	129
1880	—	2·8	32·3	251
1885	—	13	13·6	154
1890	13	12·1	17·9	380
1891	14	12	17	416
1892	21·5	17·8	15	354

The partial awning-deck vessels built last year were therefore over a fifth of the total production for cargo purposes, or an increase of 7½ per cent. for the year, while the spar-deck type had increased by nearly 6 per cent., which is remarkable considering that a large number of the partial awning-deck vessels are of a comparatively small size, the spar-deck type averaging a much larger tonnage. The most significant figures, however, relate to the three-deck type; the drop from 31 per cent. to 15 per cent. in the period named is perhaps partly accounted for by the large number of these vessels lost in the later '70's and early '80's. It is a matter for regret if the loss of the relatively narrow beamed vessels built at that time interferes with the production of a type which is undoubtedly the strongest constructed, and best adapted for the carrying of cargoes of great specific density, at a cost only slightly higher than the spar-deck class.*

The increase of the spar-deck vessels from 5 per cent. to 18 per cent. is a satisfactory feature of the table, and shows that this type is to a certain extent taking the place of the three-deck; the two complete 'tween-decked classes combined holding a fair proportion to the total, and showing an advance of about 4 per cent. for the last year over the previous one.

One of the reasons for the more general adoption of vessels with part or complete 'tween-deck space is the steadily increasing size of all types, the depth of hold of single-deck vessels becoming too great for the safe carriage of a large number of general cargoes. Lloyd's annual statement shows this increase in the average gross tonnage; but of the vessels there named a large proportion are craft of a very small and special class, and affect the proportion for vessels of the size the writers are dealing with; they therefore give the average gross tonnage of vessels of all types built

* See page 287.

for general cargo purposes by Messrs. Joseph L. Thompson & Sons, of Sunderland, during the last fifteen years, considering that these returns may be taken as a fair representation of the general and gradual increase for the United Kingdom :—

AVERAGE GROSS TONNAGE PER VESSEL.

Year.	Average Gross Tonnage per Vessel.	Year.	Average Gross Tonnage per Vessel.
1878	1,504	1886	2,225·5
1879	1,682	1887	2,107
1880	1,656·5	1888	2,169
1881	1,928	1889	2,307
1882	2,138	1890	2,464
1883	2,016·5	1891	2,663·5
1884	1,374	1892	2,892
1885	2,214		

The considerable reduction in the average gross tonnage for the year 1884 is accounted for by the fact that, owing to the commercial depression, several vessels of a small size were built for special trades and the average thus reduced, it is therefore rather unfair to consider the return for this year as a representative one.

Lloyd's Table No. 3 in the annual summary of shipbuilding returns will prove additionally useful if the total gross tonnage were given for each of the grades named.

The larger class of vessel for many trades, such as for cargoes of a light, and some of a heavy description, is a better all-round property for the owner when fitted with 'tween-decks; and although there is a type of vessel which is best adapted for any special trade; the point for most of owners to decide is which is the best adapted for all-round trading, or in other words for a "tramp." This, therefore, resolves itself very much into a question of size; the well and partial awning-deck types having proved admirably adapted for general cargo purposes. But as sizes increase, and as these types are at present constructed, the writers consider that the limit has been reached; and although on the curves and tables annexed partial awning-deck vessels are shown up to 5,327 tons deadweight, they venture to think that this is much beyond a prudent size.

Large steamers are proportionately cheaper to build and work than

small ones, and it may be taken as a consequence that lower average rates of freights have followed the increase in size of all types, and considerably diminish the earning capacities of smaller vessels. There must, however, always be a fair trade for those with their proportionally shallow draught and quicker despatch. Increasing competition also tends to lower freights, and this in its turn will decide the type which, owing to adaptability and economical working, together with the least possible cost of production, is best fitted to meet most of the requirements of a general trade.

The great difference between the various types, from an owner's point of view (omitting the strength of structure), is one of single as compared with double-decks, and all the different types built at present only show the variety of ways in which this requirement may be obtained, with varying results so far as cost and capacities are concerned; the partial awning-deck type is merely the adaptation of the two principles to meet the demands of a general trader.

A single-decked vessel is better suited to the carrying of bulk cargoes, such as coal, ore, grain, cotton, deals, etc., than one fitted with 'tween-decks; and in nearly all cases the loading and discharging rates are lower, at least in the United Kingdom. But as vessels are now not often built to suit any particular trade, extreme depth of hold will limit the employment of this type for many cargoes of a light description, such as case and barrel goods, etc., and when this reaches over, say, 20 feet, 'tween-decks are advisable, because there is a risk of crushing the lower tiers, and owners are finding the great depth of the after-holds of the larger partial awning-deck vessels objectionable on this account.

'Tween-deck ships are most suitable for carrying general cargoes, such as cases, barrels, casks, fruit, and every description of light goods, and even shippers of such cargoes as rice are now showing a preference for these vessels, when a large cargo is to be carried, and on the whole they will probably find a larger range of employment, especially if of a proportionally shallow draught.

The spar-deck vessels, when of a large size, are well adapted to the requirements of a general cargo trade, and having a greater freeboard than the three-deck type have a longer range of stability: the value of which cannot be overstated. On the other hand, the partial awning-deck vessel amidships and forward has a still greater freeboard, and therefore a higher working platform, but this advantage is to some extent modified by the lower quarter-deck aft.

One of the objections to the spar-deck type is the increased working

expenses incurred through the larger register tonnage, which is a permanent charge on the vessel's earnings. It is to be desired that some modification in the tonnage laws should be made, which would hold a fairly true relationship to the vessel's capacity, irrespective of the question of type which at present affects the total unduly; and probably the load displacement basis would be the fairest solution, and would be comparatively easy of application now that there is a fixed load-line. The present method of calculating the tonnage penalises an owner who is desirous of giving his vessel a good freeboard height, and it cannot be considered a fair measure of the vessel's earning powers or the responsibilities she incurs.

This matter was very fully considered on the reading of Mr. James's paper "On Tonnage Measurement,"* but it may be of interest to draw attention to the considerable differences which occur in vessels of the same displacement and draught, although of different types, as shown on Table I. The three-deck vessels carrying less deadweight than the partial awning-deck type have a smaller net tonnage, while the spar-deck ships carrying about the same deadweight as the three-deck have a larger net tonnage than the partial awning-deck type. This, of course, is owing to the different heights above the load-line; but it is open to discussion whether vessels offering many advantages, both from a commercial and a sea-worthy point of view, should be handicapped by such an appreciable addition to their working expenses.

In fixing on the type best adapted for any particular trade due regard must be paid to the stability of the various structures, all of which are, or can be made, sufficiently strong to stand the stress of ordinary trading; but in the case of spar-deck vessels an improvement can be made which will not increase their cost of production, and will make them very much stronger than they are at present. This can be done by having the increased scantling of the sheer and stringer plates at the spar instead of the main-deck height, and as these vessels are being built of a large size for Atlantic and other heavy work an alteration of this nature would materially add to their efficiency. This is already the rule for the three-deck class, the material being distributed to better advantage, and the structure more capable of resisting longitudinal strains—a point of the utmost importance when considered in connection with the long shallow vessels so common at the present time.

It is not possible to state definitely what are the best proportions for a steamer, so many commercial and other considerations having to be

* See page 105, Vol. VIII., *Transactions of the North-East Coast Institution of Engineers and Shipbuilders.*

taken into account. Lloyd's rules practically fix the weight of a vessel, and therefore the cost, and with the compulsory load-line the carrying powers are limited. Draught of water is one of the most important requirements, and is restricted by the shallowness at the entrance of a large number of English, Baltic, Black Sea, Mediterranean, and some American ports, while even the Suez Canal allows a draught of only about 25 feet 6 inches. Again, the question of length has to be considered in the case of the Danube, Mobile, Wilmington, etc. Therefore the owner who purposes trading extensively at these ports must have his vessel built accordingly, and if a large carrying power is required, the builder is left to increase the beam only (which is one of the cheapest ways to increase capacity), have a full bilge, and box-like ends. The beam again is restricted, because if a vessel has to be sea-kindly with, say homogeneous cargoes, this must not be excessive. Increase of beam gives least increase of wetted surface, and therefore of frictional resistance to speed; but in the case of large steamers, where the draught is limited, it is perhaps better, up to a certain limit, to increase length rather than beam. The relative proportions of length, beam, and draught must be carefully considered if a fair speed efficiency is to be obtained.

In all probability the dimensions of ordinary cargo steamers will go on increasing, and as the proportions must be kept in a fair ratio to obtain efficient results, the port authorities offering the greatest depth of water will receive a larger share of trade. For efficient and therefore economical propulsion, a good draught, by keeping the propeller more fully immersed, is better than excessive length; while, on the other hand, relatively short steamers are difficult to drive against a head sea.

Before fixing the dimensions of any of the vessels discussed in this paper, the writers made a careful analysis of the dimensions of a large number of vessels built within the last few years, and after considering the matter in relation to deadweight and cubic capacity, have worked to the proportions shown on Table II. as those which give satisfactory results on this basis, and are in fair agreement with the limits of commercial and speed efficiency already referred to. The dimensions named are not put forward as absolutely the best possible; this is a matter upon which builders hold different opinions (as could be shown by the proportions of the vessels referred to which were taken from Lloyd's Register), and upon which some owners have ideas which builders are compelled to respect when dimensions are being fixed. The President has already noted that the life of a ship appears to depend upon the country where she is built, and our investigations have shown that to some extent her proportions are

governed by locality. Of 90 partial awning-deck vessels the average proportion beams in length were for the three leading North-East ports :—

Wear	7·43
Tyne	7·53
Tees and Hartlepools ...	7·59

showing that the Wear builders favour a slightly wider vessel than the Tyne or Tees. The proportion depth in beam is practically the same in each case. The partial awning-deck vessels' dimensions (Table I.) were fixed to take advantage of Lloyd's grades, each ship being worked as close as possible to the succeeding grades, and the table therefore shows the range of dimensions between the various grades. The following figures show the percentage of displacement and weight of material increase between the grades:—

PERCENTAGE OF DISPLACEMENT AND WEIGHT INCREASE.

All Types.		Partial Awning-deck.	Spar-deck.	Three-deck.
No.	Displacement.	Weight.	Weight.	Weight.
2	10·80	8·61	7·04	8·32
3	10·95	9·98	6·76	8·61
4	9·93	9·96	7·11	8·87
5	11·75	11·65	9·88	9·40
6	12·28	13·12	14·52	12·17
13	18·25	—	23·17	23·10

This table really only applies to the partial awning-deck vessels, because full advantage is not taken of the spar and three-deck grades, as shown on Table III. To have a fair basis of comparison between the three types it was necessary to keep the length, beam, and *draught* the same in each class. Therefore, in actual practice, the dimensions of the spar and three deck-ships could, in almost every case, be increased, the cost advancing in about the same proportion, and the percentage ratios given in the table above would probably vary very slightly.

It is not always possible to take full advantage of Lloyd's grades; in some cases the numerals may work out closely for all grades, in others the frame numerals may be just over, as in the case of No. 6, etc., or the equipment, as in the case of No. 3, etc. Having decided to work as

closely as possible to the plating grades, both the frame and equipment requirements for two widely different sized vessels may be the same as shown in Nos. 3 and 4.

It will be noticed that the plating and equipment grades are the same for partial awning and three-deck types, while the frame grades of Nos. 14 and 16 are lower for the three than the partial awning-deck type. The spar-deck frame grade is two grades lower than the three-deck for No. 8; in all other cases it is one grade lower. The spar-deck plating grade is the same as the three-deck for No. 12, the other cases being one grade lower. But the equipment is one grade higher in the cases of Nos. 7, 10, and 13, while Nos. 8, 9, 11, and 12 are on the same grades.

Attention may further be directed to the equipment grades, all the vessels are of the same displacement, and so far as that is concerned, all the types ought to have the same numbers. But if wind resistance above the water-line is to be considered, then the three-deck vessel with a lower freeboard should have a reduced number. That, however, is not so, for the table shows that partial awning and three-deck types are alike; spar-deck vessels are, however, a grade higher in three cases, while in the remaining four cases the three types are on the same grades.

The tank grades of Nos. 1 and 3 partial awning-deck vessels are one higher than the corresponding spar and three-deck types. The others are the same in each case, with the exception of Nos. 8 and 11, which are one grade lower than either the partial awning or three-deck types.

Though hardly within the scope of this paper to criticise the basis of Lloyd's grades, it is impossible to take out a number of vessels of different dimensions for either the same or varying types, without having to notice a large number of anomalies. It may therefore be excusable, and perhaps useful, to thus briefly draw attention to some of the at least apparent inconsistencies. At the same time it may again be pointed out that the present rules by partly ignoring the form of the midship section, displacement, and fineness of the ends favour the construction of the abnormally full vessels which are so generally condemned, though persistently built; the scantling being the same for either fine or full forms, though the tendency of the fuller models is to strain excessively in heavy weather.

Another objectionable feature is the penalty placed on increase of depth, as compared with increase of beam, although a vessel is made considerably stronger by making her deeper instead of wider.

Reference to Table II. will show that the deadweight carried per ton of material decreases in the larger vessels, or in other words, the weight of scantling increases, after a certain size, more quickly than the dimensions;

and the table of percentages on page 282 shows that the weight therefore increases more rapidly than the displacement. This is not so, however, with the equipment weight (including everything except iron and steel material) and weight of machinery, which are a larger proportion of the total displacement in small than large steamers, and thus the reduced cost of large vessels as compared with small ones is partly explained. Power being practically a measure of the coal consumption it will be seen that, with vessels of similar proportions, as the size increases the power per ton displacement, or deadweight, decreases, and hence it is that a ton of cargo is carried with a smaller expenditure of power, coal, and cost in a large vessel as compared with a small one.

The percentage of increase of deadweight and powers of the vessels given on Table I. are as follows:—

PERCENTAGE OF INCREASE OF DEADWEIGHT AND POWER.

Partial Awning-deck.			Spar-deck.			Three-deck.		
No.	Dead-weight.	Power.	No.	Dead-weight.	Power.	No.	Dead-weight.	Power.
2	11·99	7·35	8	12·68	6·99	15	12·58	6·79
3	12·12	7·74	9	13·20	7·77	16	9·18	7·24
4	10·44	6·77	10	11·29	7·13	17	10·90	6·75
5	12·47	8·66	11	13·00	8·11	18	13·00	8·80
6	12·50	8·90	12	12·13	8·42	19	12·78	8·72
			13	18·13	12·79	20	18·19	12·85

Or, to put the figures into a more comprehensive form, the total increase between the lowest and highest of the vessels named is:—

PERCENTAGES OF INCREASE BETWEEN THE LOWEST AND HIGHEST.

Type.	Deadweight.	Power.
Partial Awning-deck ...	73·42	46·13
Spar-deck	112·48	63·33
Three-deck	111·04	63·11

It does not, however, follow that large steamers always pay better than smaller ones, though they are manned, and therefore provisioned, at a smaller rate per ton; for when over a certain size they become berth

boats, and are sometimes difficult to fix for full cargoes, the delays often resulting in lower freights being accepted, which again react on the smaller classes.

The densities of cargoes required to immerse each vessel to her load marks are shown on Table II., the averages being :—

Partial awning-deck	54·83	cubic feet per ton.
Spar-deck	54·25	" "
Three-deck	52·67	" "

This is for cargo space solely, the weight of side bunkers having been deducted, and in the spar and three-deck class the bridge side bunkers also.

The three-deck type require cargoes of the greatest specific density to immerse them to their full draught, the spar-deck vessels come next, and the partial awning-deck class require a slightly lighter cargo than the spar-deck.

The proportions of all the vessels named allow a good metacentric height, which is the measure of their initial stability.

METACENTRIC HEIGHTS.

Partial Awning-deck.			Spar-deck.			Three-deck.		
No.	Coal Cargo.	Homogeneous Cargo.	No.	Coal Cargo.	Homogeneous Cargo.	No.	Coal Cargo.	Homogeneous Cargo.
1	2·04	1·68	7	2·59	1·96	14	3·13	2·50
2	1·98	1·44	8	2·42	1·75	15	2·84	2·17
3	1·96	1·56	9	2·51	1·82	16	3·00	2·31
4	1·93	1·51	10	2·59	1·87	17	3·00	2·28
5	2·08	1·48	11	2·62	1·87	18	2·97	2·22
6	1·95	1·46	12	2·56	1·78	19	2·92	2·14
			13	2·39	1·55	20	2·82	1·98

The three-deck vessels' metacentric heights are much greater than either of the other types; and although the writers are not aware of any authority who has definitely fixed a limit either for the minimum or maximum, it may safely be taken that all the above are amply provided with initial stability, agreeing with actual vessels built by Messrs. Joseph L. Thompson & Sons, which have proved to be excellent sea vessels. Provided a vessel has sufficient initial stability, her behaviour at sea very much depends on the disposal of the weights she is carrying, and therefore is well within the control of the captain.

The variations in the freeboard ratios are interesting, showing as they do the increase due to the larger dimensions, and the considerable advance in the three-deck type is noteworthy. Put into percentages of the depth moulded the differences are as follows:—

FREEBOARD PERCENTAGES OF DEPTH MOULDED.

Partial Awning-deck.		Spar-deck.		Three-deck.	
No.	Freeboard per Cent. of Depth Moulded.	No.	Freeboard per Cent. of Depth Moulded.	No.	Freeboard per Cent. of Depth Moulded.
1	6·70	7	19·19	14	15·15
2	7·32	8	19·56	15	16·49
3	7·39	9	19·98	16	16·61
4	8·49	10	20·44	17	17·59
5	9·02	11	20·85	18	18·30
6	9·66	12	21·79	19	19·34
		13	23·52	20	20·97
Increase 2·96		Increase 4·33		Increase 5·82	

The length, beam, and draught for the corresponding vessels of each type are the same, and the proportions being advanced in about the same ratios it is difficult to understand why the increase required for the three-deck vessels should be so much in excess of that for spar-deck. This is one of many anomalies in the freeboard tables which will doubtless be rectified in good time, and it will then be possible to make a fairer comparison between different types, the value of the classes varying in proportion and on a sound basis.

It should be stated that the spar-deck vessels have an allowance of freeboard on account of their reverse frames being carried the full height and additional strength fitted. This, however, only affects these percentages very slightly, because, unless allowed for, the vessels would have to be made a greater moulded depth to obtain the draught; this would add to the cost, and increase the cubic capacities, which would then more nearly approach the partial awning measurement space.

The cost curves (Plates LVI. and LVII.) of the spar and three-deck classes are shown as a percentage of increase over the partial awning-deck type (Plate LV.), no curve being given for this type as it is taken as the basis of comparison; the point worthy of note being the gradual fall in the price per ton deadweight as the size increases, and the fact that in the

first case the three-deck vessel would be cheaper to build than spar-deck, the succeeding five sizes of each class showing a varying ratio. The following table shows actual results of the estimates of cost reduced to a deadweight basis:—

PERCENTAGE OF INCREASED COST OF SPAR AND THREE OVER PARTIAL AWNING-DECK VESSELS.

Deadweight.	Spar-deck.	Three-deck.
3,036	5·29	4·35
3,400	4·68	5·12
3,812	3·00	4·42
4,210	1·30	2·93
4,735	·67	1·84
5,327	—	1·88

In actual practice the comparison of the costs of, say, the last three, would be slightly different, because it is usually found advisable to fit a considerable amount of extra scantling in the larger partial awning-deck vessels, a reduction of freeboard is thereby obtained and the deadweight increased. This would, however, not affect the rate per ton to any great extent, and the figures named may be taken as practically correct. The proportions of any of the vessels could be varied slightly, and the cost would not be affected appreciably, provided the grades are not altered, and the weight is kept about the same.

It may be noted that although the cost curve for the three-deck type commences to rise at both the smaller and larger sizes, this is only when the costs are reduced to a deadweight basis and put into percentages of increase over the partial awning-deck class. An actual curve drawn for any of the types would show a steady fall of cost per ton deadweight from the smallest to the largest size.

All the estimates have been carefully prepared, and the figures and curves are the results, without any attempt having been made to make one vessel, or type, appear better than another. In actual practice the results shown will be as nearly correct as it is possible to estimate them, with all the facilities of an elaborate cost and estimating system.

By adding extra scantling, and in other ways, advantages can be obtained for all the types; but it was considered better that the figures should be simply based on Lloyd's rules, without any additions, except those named on page 286, and the basis of comparison is a reasonably fair one. This also applies to the tonnage measurements, which could be

considerably reduced by fitting frames of increased strength and size, instead of web-frames, thus saving about 3 inches in the tonnage widths; but web-frames are the usual practice at present, and the correction can easily be made by those who wish to use the curves or figures.

The powers are all estimated to drive the vessels at a regular working speed of 9½ knots, and are based on the actual performances of a large number of vessels. The displacement coefficient in every case is ·78, which is the highest the writers consider advisable, and is the fullest that Messrs. Joseph L. Thompson & Sons ever estimate for. The writers consider that finer vessels, with slightly higher power, will be found to pay better over a series of voyages, especially if these are for moderate distances, than the excessively full modelled and low-powered boats so frequently built at present.

The extra full vessels of, say, ·80 or ·82 require very little more power than those having coefficients of ·78 to drive them the same speed on *smooth water trials.*

It was the writers' intention to have given a speed curve showing the different powers required to drive the bluffer models on trial, but although there must be an increase in resistance, it is so small when the vessels are driven at a *moderate speed* in smooth water, that the differences could easily be accounted for by errors of observation, etc., and this proposed curve would be practically useless. It is well known that in actual working the trial results for full vessels are not maintained, they being difficult to drive against a head sea, and are altogether not such satisfactory vessels as the moderately finer forms of, say, ·74 to ·76 coefficient. These questions of form and speed are matters which *owners* will have to settle for themselves, most builders of both hulls and engines do not care for the square-ended and full bilged forms; but so long as owners are satisfied to consider the value only from a deadweight basis, without any regard to speed efficiency and sea qualities, these ungainly vessels will continue to be constructed.

It is difficult to obtain accurate results of the speed performances of ordinary cargo vessels. Progressive trials are held occasionally and some data taken, but a large proportion of these boats are never tried, and it is really not known whether the model and machinery are adapted for each other. They are doubtless supposed to give satisfactory results, and other vessels and engines are built on the same lines, much in the way that the forms of wooden vessels were often decided on. It is therefore to be desired that owners would allow builders greater facilities for

progressive speed trials which would show the most economical speed; as there is a speed which is easily possible for any model, and to drive the vessel above this is an extravagant use of power, while to work at a lower speed is to lose time and to waste fuel. Obtaining the maximum power from an engine is equivalent to sacrificing a large amount of economy; and the only way to learn the most economical power is by means of progressive trials.

The cost of engines increase in about the same ratio as the power. If, therefore, a vessel is fitted with such an excess of power which it is found uneconomical to use, an unremunerative addition is made to the capital cost, and there is a permanent reduction of deadweight.

The writers venture to think that the successful cargo vessel of the future will be of a higher speed than the present, and that more regard will be paid to a form which will give the most efficient result of the employment of power.

The writers are indebted to Messrs. George Clark, Limited, of Sunderland, for kindly supplying a series of load progressive trial results, which practically support the statements as to the small differences in power required to drive vessels of varying fulness of model at moderate speeds on smooth water trials; and to Messrs. Joseph L. Thompson & Sons for placing the whole of the necessary information in their hands, and for allowing their estimating staff to work out some of the calculations.

TABLE I.—DIMENSIONS, WEIGHT, CAPACITIES, TONNAGES, AND POWER.

Number.	Dimensions.						Draught Moulded.	Lloyd's Summer Free-board.	Skin Displacement.		Dead-weight.	Weights.			Tonnages.		Gross Cubic Capacities.	Indicated Horse-power.
	Length B. P.	Breadth Extreme.	Depth Moulded.	Depth Lower Holds.		Height Tween Decks.			Load.	Light.		Material.	Equipment.	Engines.	Gross.	Net.		
				M. Dk.	R.Q.Dk.													
PARTIAL AWNING-DECK.																		
	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.										
1	282 3	37 4½	20 6	18 1	22 7	6 9	19 2	1 4½	4,507	1,471	3,036	941	290	240	2,131	1,359	154,324	1,047
2	290 6	38 5	21 7½	19 2½	23 8½	„	20 1	1 7	4,994	1,594	3,400	1,022	307	265	2,320	1,481	174,500	1,124
3	301 9	39 11	22 3	19 8½	24 2½	„	20 7¾	1 7¾	5,541	1,729	3,812	1,124	325	280	2,583	1,652	195,700	1,211
4	313 9	41 3	23 0½	20 6½	25 0½	„	21 1½	1 11½	6,091	1,881	4,210	1,236	350	295	2,857	1,833	214,390	1,293
5	326 0	42 10	24 0	21 6	26 0	„	21 10½	2 2	6,807	2,072	4,735	1,380	372	320	3,210	2,069	237,600	1,405
6	339 6	44 8	25 0	22 4½	26 10½	„	22 7½	2 5	7,643	2,316	5,327	1,561	405	350	3,564	2,304	263,188	1,530
SPAR-DECK.																		
7	282 3	37 4½	23 8	14 5		7 0	19 2	4 6½	4,507	1,542	2,965	1,009	293	240	2,154	1,369	138,436	1,047
8	290 6	38 5	24 11	15 8½		„	20 1	4 10½	4,994	1,653	3,341	1,080	308	265	2,380	1,511	158,100	1,124
9	301 9	39 11	25 9	16 4½		„	20 7¾	5 1¾	5,541	1,761	3,782	1,153	328	280	2,629	1,683	180,200	1,211
10	313 9	41 3	26 6	17 0		„	21 1½	5 5	6,091	1,882	4,209	1,235	352	295	2,899	1,856	200,444	1,293
11	326 0	42 10	27 7	18 1		„	21 10½	5 9	6,807	2,054	4,756	1,357	377	320	3,233	2,088	225,300	1,405
12	339 6	44 8	28 10½	19 3		„	22 7½	6 3½	7,643	2,311	5,333	1,554	407	350	3,656	2,376	252,786	1,530
13	362 0	47 2	31 0	21 3		„	23 9	7 3½	9,038	2,738	6,300	1,914	454	370	4,377	2,857	307,058	1,730
THREE-DECK.																		
14	282 3	37 4½	22 6½	12 9½		7 6	19 2	3 5	4,507	1,527	2,980	997	290	240	2,057	1,303	134,685	1,047
15	290 6	38 5	24 0	14 1		„	20 1	3 11½	4,994	1,639	3,355	1,080	294	265	2,275	1,442	155,100	1,124
16	301 9	39 11	24 8½	14 8		„	20 7¾	4 1¼	5,541	1,778	3,763	1,173	325	280	2,509	1,601	175,800	1,211
17	313 9	41 3	25 7	15 7		„	21 1½	4 6	6,091	1,918	4,173	1,277	346	295	2,760	1,771	194,758	1,293
18	326 0	42 10	26 9	16 7		„	21 10½	4 10¾	6,807	2,092	4,715	1,397	375	320	3,118	2,010	217,500	1,405
19	339 6	44 8	28 0	18 0		„	22 7½	5 5	7,643	2,322	5,321	1,567	405	350	3,556	2,308	243,115	1,530
20	362 0	47 2	30 0	19 9		„	23 9	6 3½	9,038	2,749	6,289	1,929	450	370	4,221	2,759	296,946	1,730

TABLE II.—RATIOS.

Number.	Dimensions.						Displacement.								Deadweight.							Capacities.					I.H.P. per Ton of Engine Weight.
							Weight.					Tonnage.			Weight.				Tonnage.						Tonnage.		
	Breadth to Length.	Depth to Length.	Depth to Breadth.	Draught to Breadth.	Draught to Depth Moulded.	Freeboard to Depth Moulded.	Material.	Equipment.	Engines.	Light.	Dead.	Gross.	Net.	I.H.P.	Material.	Equipment.	Engines.	Light.	Gross.	Net.	I.H.P.	Load Displacement.	Deadweight.	Deadweight less Bunkers.	Gross.	Net.	
PARTIAL AWNING-DECK.																											
1	7·55	13·77	1·82	1·95	1·07	14·91	4·79	15·54	18·78	3·06	1·48	2·11	3·32	4·30	3·23	10·47	12·65	2·06	1·42	2·23	2·90	34·24	50·83	55·41	72·42	113·58	4·36
2	7·56	13·43	1·78	1·91	1·08	13·66	4·89	16·27	18·84	3·13	1·47	2·15	3·37	4·44	3·33	11·07	12·83	2·13	1·46	2·30	3·02	34·94	51·32	55·62	75·21	117·82	4·34
3	7·56	13·56	1·79	1·93	1·08	13·52	4·93	17·05	19·79	3·20	1·45	2·14	3·35	4·57	3·39	11·73	13·61	2·20	1·48	2·31	3·15	35·32	51·34	55·43	75·76	118·46	4·32
4	7·61	13·62	1·79	1·95	1·09	11·77	4·93	17·40	20·65	3·24	1·45	2·13	3·32	4·71	3·41	12·03	14·27	2·24	1·47	2·30	3·26	35·20	50·92	54·92	75·04	116·96	4·38
5	7·61	13·58	1·78	1·96	1·10	11·08	4·93	18·30	21·27	3·28	1·44	2·12	3·29	4·84	3·43	12·73	14·80	2·28	1·47	2·29	3·37	34·90	50·18	54·11	74·02	114·84	4·39
6	7·60	13·58	1·79	1·97	1·10	10·35	4·90	18·87	21·84	3·30	1·43	2·14	3·32	4·99	3·41	13·15	15·22	2·30	1·49	2·31	3·48	34·43	49·41	53·52	73·85	114·23	4·37
SPAR-DECK.																											
7	7·55	11·93	1·58	1·95	1·23	5·21	4·47	15·38	18·78	2·92	1·52	2·09	3·29	4·30	2·94	10·12	12·35	1·92	1·37	2·17	2·83	30·72	46·69	53·55	64·27	101·12	4·36
8	7·56	11·66	1·54	1·91	1·24	5·11	4·62	16·21	18·84	3·02	1·49	2·10	3·30	4·44	3·09	10·85	12·61	2·02	1·40	2·21	2·97	31·66	47·32	53·98	66·43	104·63	4·24
9	7·56	11·72	1·55	1·93	1·25	5·01	4·81	16·89	19·79	3·15	1·46	2·11	3·29	4·57	3·28	11·53	13·51	2·15	1·44	2·24	3·12	32·52	47·64	54·10	68·54	107·07	4·32
10	7·61	11·84	1·56	1·95	1·25	4·90	4·93	17·30	20·65	3·24	1·44	2·10	3·28	4·71	3·41	11·96	14·27	2·23	1·45	2·26	3·25	32·91	47·62	54·10	69·14	108·00	4·38
11	7·61	11·82	1·55	1·96	1·26	4·79	5·02	18·06	21·27	3·31	1·43	2·11	3·26	4·84	3·50	12·61	14·66	2·31	1·47	2·28	3·38	33·09	47·37	53·81	69·69	107·90	4·39
12	7·60	11·76	1·55	1·97	1·28	4·59	4·92	18·78	21·84	3·31	1·43	2·09	3·21	4·99	3·43	13·10	15·23	2·31	1·46	2·24	3·48	33·07	47·40	53·86	69·14	106·39	4·37
13	7·67	11·68	1·52	1·99	1·30	4·25	4·72	19·91	24·43	3·30	1·43	2·06	3·16	5·22	3·29	13·88	17·03	2·30	1·44	2·20	3·64	33·97	48·74	56·37	70·15	107·47	4·67
THREE-DECK.																											
14	7·55	12·52	1·66	1·95	1·18	6·60	4·52	15·54	18·78	2·95	1·51	2·19	3·46	4·30	2·99	10·28	12·42	1·95	1·45	2·29	2·84	29·88	45·20	51·70	65·48	103·36	4·36
15	7·56	12·10	1·60	1·91	1·19	6·06	4·62	16·99	18·84	3·05	1·45	2·19	3·46	4·44	3·11	11·41	12·66	2·05	1·47	2·33	2·98	31·06	46·23	52·61	68·17	107·56	4·24
16	7·56	12·21	1·61	1·93	1·20	6·02	4·72	17·05	19·79	3·12	1·47	2·21	3·46	4·57	3·21	11·58	13·44	2·12	1·50	2·35	3·10	31·73	46·72	53·01	70·07	109·81	4·32
17	7·61	12·26	1·61	1·95	1·21	5·68	4·77	17·60	20·65	3·17	1·46	2·21	3·44	4·71	3·27	12·06	14·15	2·17	1·51	2·36	3·22	31·97	46·67	52·98	70·56	109·97	4·38
18	7·61	12·19	1·60	1·96	1·22	5·46	4·87	18·15	21·27	3·25	1·44	2·18	3·39	4·84	3·37	12·57	14·73	2·25	1·51	2·34	3·35	31·95	46·13	52·33	69·76	108·21	4·29
19	7·60	12·12	1·59	1·97	1·24	5·17	4·88	18·87	21·84	3·29	1·44	2·15	3·31	4·99	3·39	13·14	15·20	2·29	1·50	2·30	3·48	31·81	45·69	51·77	68·37	105·34	4·37
20	7·67	12·07	1·57	1·99	1·26	4·77	4·68	20·08	24·43	3·29	1·44	2·14	3·28	5·22	3·26	13·97	17·00	2·29	1·49	2·28	3·63	32·85	47·22	54·32	70·35	107·63	4·67

TABLE III.—LLOYD'S NUMERALS.

	Partial Awning-deck.			Spar-deck.			Three-deck.		
	No.	Grades.	Numerals.	No.	Grades.	Numerals.	No.	Grades.	Numerals.
Frame	1	73-76	75·93	7	68-71	68·26	14	71-73	72·99
Plating	"	19,900-21,300	21,285	"	18,700-19,900	19,130	"	19,900-21,300	20,452
Tank	"	21,000-24,000	"	"	18,000-21,000	"	"	18,000-21,000	"
Equipment	"	21,280-24,220	23,945	"	24,220-27,140	24,325	"	21,280-24,220	23,653
Frame	2	76-80	79·25	8	71-73	71·84	15	76-80	77·02
Plating	"	21,300-22,900	22,861	"	19,900-21,300	20,725	"	21,300-22,900	22,220
Tank	"	21,000-24,000	"	"	18,000-21,000	"	"	21,000-24,000	"
Equipment	"	24,220-27,140	25,718	"	24,220-27,140	26,084	"	24,220-27,140	25,500
Frame	3	80-85	82·03	9	73-76	75·03	16	76-80	79·93
Plating	"	22,900-24,600	24,595	"	21,300-22,900	22,492	"	22,900-24,600	23,960
Tank	"	24,000-28,000	"	"	21,000-24,000	"	"	21,000-24,000	"
Equipment	"	27,140-30,020	27,669	"	27,140-30,020	28,065	"	27,140-30,020	27,407
Frame	4	80-85	84·97	10	76-80	77·91	17	80-85	83·07
Plating	"	24,600-26,500	26,492	"	22,900-24,600	24,288	"	24,600-26,500	25,897
Tank	"	24,000-28,000	"	"	24,000-28,000	"	"	24,000-28,000	"
Equipment	"	27,140-30,020	29,803	"	30,020-32,820	30,089	"	27,140-30,020	29,487
Frame	5	85-91	88·54	11	80-85	81·63	18	85-91	86·97
Plating	"	26,500-28,700	28,686	"	24,600-26,500	26,445	"	26,500-28,700	28,178
Tank	"	28,000-33,000	"	"	24,000-28,000	"	"	28,000-33,000	"
Equipment	"	30,020-32,820	32,271	"	30,020-32,820	32,533	"	30,020-32,820	31,972
Frame	6	91-97	92·31	12	85-91	86·06	19	91-97	91·56
Plating	"	28,700-31,200	31,160	"	28,700-31,200	29,042	"	28,700-31,200	30,901
Tank	"	28,000-33,000	"	"	28,000-33,000	"	"	28,000-33,000	"
Equipment	"	32,820-35,450	35,055	"	32,820-35,450	35,446	"	32,820-35,450	34,910
Frame	—	—	—	13	91-97	92·85	20	97-103	97·85
Plating	—	—	—	"	31,200-33,900	33,420	"	33,900-36,800	35,220
Tank	—	—	—	"	33,000-38,000	"	"	33,000-38,000	"
Equipment	—	—	—	"	39,600-43,600	40,282	"	35,450-39,600	39,454

DISCUSSION.

Mr. G. W. SIVEWRIGHT, in opening the discussion on this paper, congratulated the authors on the manner in which it was written, and he considered it would make a valuable contribution to the Transactions of the Institution. He quite agreed with the authors that the Hartlepools had done their best to protect the type of vessel known as the well-deck cargo steamer. Although this design had been most fiercely assailed by the Board of Trade and other authorities, yet shipowners had been able to prove from the Board of Trade's own statistics that this class of vessel was one of the safest designs afloat. The manner in which this type had been worried out of existence was not at all creditable, and, to his mind, clearly proved there ought to be a better method of regulating shipping legislation than what at present existed. In connection with the so-called improved or semi-awning-deck type of vessel, although this design had its birth in the Hartlepools, and a large number had been built in that district, yet he would like emphatically to state that they did not claim that this type was an improvement on what they had before; it was merely the outcome of a compromise with the authorities. He thought the authors of the paper had struck the right keynote to the whole question when they stated the "economical working in general trading" settles the design of vessel to build. Having had a varied experience with cargo boats, he (Mr. Sivewright) would like to put his views before the meeting with reference to the different types. The general adoption of 'tween-decks, as mentioned by the writers, he thought, was not so much due to cargo requirements as to the action of Lloyd's compelling shipowners and shipbuilders to fit 'tween-decks whether it was suitable for their trade or not. He was sure that for general cargo trading a double-deck was not necessary so far as cargo requirements were concerned, and if "economical working in general trading" settles the design, a single-deck cargo steamer would make money whilst a double-deck steamer would not pay her way. He thought the authors had admitted this when they stated that a single-deck cargo vessel was better able to carry coal, ore, grain, cotton, deals, etc., than one fitted with 'tween decks; this description of cargo was really the deadweight trading of the world, and the other kinds of cargo mentioned, such as barrel goods, etc., was exceptional cargo, and as a rule could only be made to pay in connection with passenger traffic, or subsidised trades in which the ordinary cargo steamer did not compete. But probably the greatest drawback to a double-deck ship, which she would never be able to get over, would be the difficulty in stowing the lower holds with the

maority of cargoes, and the additional delay and expense in loading and discharging. A double-deck ship loaded down to her freeboard mark with a medium deadweight cargo and bunkers filled—on account of the extra weight of ship and extra dunnage, etc.—there is a large amount of capacity left in the holds, consequently a shipowner has to build a bigger ship to do his work than would be required if she was a single-decker. If the ships got to an extra large size, he thought it would still be possible to have them of the single-deck type with bridge, poop, and forecastle, and if any extra strength was required in the holds, this could be got with a tier of beams, stringers, etc., but with no laid intermediate-deck; by this means cargoes would not have to be bagged, and although the extra number of beams would break a certain amount of stowage, yet the beams would help to prevent the top tier of cargo damaging the cargo at the bottom of the holds if it was of a fragile nature. This was a type of ship that had been built before, and of which he submitted a plan (see Plate LVIII.). The only real advantage ever claimed in the Hartlepools for the raised quarter-deck vessel, was that she was a single-deck ship, and they simply had to put a raised quarter-deck on to make the vessel trim when the fuller models came into vogue. There is a very interesting table on page 276 of the paper comparing the number of the different types of cargo boats built, and specially calling attention to the great increase in the spar-deck type, and the decrease of the three-deck type. He thought this statement wanted qualifying a little; as to his knowledge there was really not a pure spar-decker being built at the present day. The ship that was called a spar-deck ship now was really not a spar-decker at all, as in nearly every case the top side plating was much increased in thickness and sectional framing (or reverse bars) being carried up to the top sides, and the register societies were allowing a corresponding decrease in freeboard, and deeper loading on account of this strengthened type of spar-decker. But they were having complaints with this type of vessel as well as the semi-awning-deck of the difficulty of the crew and officers getting about to work the ship, and it would mean they would have to face the addition of a forecastle, bridge, and poop, as they had to do years ago in the old single-deck type of ship; indeed, many of the new spar-deckers had a bridge amidships for this reason, as the writers had mentioned on page 276. He would not like the members to think he was against flush-deck ships, but what he did protest against, was the building of flush-deck deeply laden vessels with no protection for the crew or vital parts of the ship. As pointed out by the writers, the anomalies in the tonnage laws had prevented

shipowners and shipbuilders from getting out the best type of ship suitable to do its work, but he could not quite agree with the writers where they advocated a displacement basis as a solution of this question. He was of opinion that a displacement basis would really only create anomalies in another direction. He quite agreed there was very little encouragement for shipowners to go to the expense of putting erections on vessels for the benefit of the crew, or working of the ship, if they were to be penalised for doing so. They had a question at point in the test case in what was known as the "Isabella" deductions. There seemed to be an impression in connection with this matter that it was a ridiculous decision, although it was settled before a competent court, with the whole matter before them. If they had to consider what was ridiculous in connection with shipping legislation, it would be necessary to start at the first and consider the whole lot of it on the same basis, as in many instances shipping laws were made by people who were not thoroughly conversant with shipping matters. It was stated before the Tonnage Commission, by an experienced and credible witness, that the law under which the "Isabella" case came was a bonus deliberately given to owners to induce them to give better light and ventilation to the engine room, and better housing of the crew, by deducting from the gross tonnage these spaces that had not been measured into the gross tonnage in the first instance. He was decidedly of opinion, if it would make a more sea-worthy ship and better officers' or crew accommodation, that owners ought to strenuously object to the "Isabella" decision being rescinded, as it was the intention to do in a year or two; and he considered that where any officers or crew were housed below a deck, such accommodation was not suitable for hot climates, or safe in a heavy sea-way. It had been suggested, as a better way of charging dues, to simply charge for the time the quays were used. This would work well in connection with docks, rivers, or canals. If it would really give a freer hand to shipbuilders and shipowners to build better ships, why charge tonnage dues at all? It was asserted on the authority of one of the largest dock companies that tonnage dues were not necessary, as they could recoup themselves from the cargo; and that if cargo or produce paid rates in every other case, why should it not pay the dues in the case of shipping? Tonnage measurement was an old-fashioned method of arriving at the carrying capacity of a ship, and was out of date and of very little use at the present moment; and the venerableness of these laws, to his mind, seemed to be the only reason why they were supported. On page 281 it is stated that "beam" is one of

the cheapest ways in increasing capacity. Of course, there may be special circumstances in connection with this remark; but his (Mr. Sivewright's) experience was, that "beam" was a most expensive way to add capacity to a ship, as 1 foot of beam only represented something like 4 inches draught of water, and was costly to build in comparison with depth. He could not quite agree with the last paragraph on page 286, without further information, as to the design of the ships, when the writers stated that small three-deck cargo boats are cheaper to build than spar-deckers. There was one part of the paper he thought that all sensible ship-builders would cordially agree with the writers, and that was where they drew such special attention to the full class of vessels they had drifted into building at the present day; and if the paper was of no further use than of impressing upon shipowners the error of building extreme dimensioned and full-bodied ships it will have served a useful purpose. It was pleasing to note that one shipbuilder had determinedly set his face against building any ship fuller than a block coefficient of ·78, and this was quite full enough for any kind of cargo boat. He was certain of this, that owners who insisted upon having their ships built up to ·82 were injuring their own interests, as it was impossible to drive a ship of this fulness with economy; and a ship of this type in a heavy sea would be liable to peculiar straining. On page 282 he noticed that the writers had called attention to the anomalies that existed in connection with certain registry rules, which had a tendency to encourage the building of full vessels. Some of the shipowning members who were present might really not fully grasp the results of the great difference that existed in the block coefficients he had quoted; but, as an illustration of the difference as regards displacement, he might state that a large steamer with a block coefficient of ·8 would equal 6,335 tons, and ·7 would equal 5,542 tons—a difference of 793 tons; and yet a shipbuilder could build the fuller coefficient ship with a very small increase of scantlings. The freeboard at ·8 would be equal to 2 feet 2½ inches to main-deck, and at ·7 would be equal to 2 feet 1½ inches to main-deck. So long as shipping legislation was on its present footing he considered they would have very little chance of getting a better or more suitable design of ship. Any law in connection with tonnage or freeboard as it now stood could be altered by an Order in Council, and practically without the people most concerned having a word to say in connection with the same. It was a surprise to many that one of the largest industries in the world could be governed in such a manner. He considered a paper of the description just read, and which covered so many vital points, was worthy of the fullest discussion.

The PRESIDENT thought there was one point he ought to make clear before they went further in this discussion. So far as the paper was concerned, it was entirely Mr. Jordan's and Mr. Marlborough's. What his firm did was this: They said—"There is the whole of the information you want, so far as regards the cost of ships, and you can make full use of the estimating staff in the way we ourselves estimate for vessels." So that the whole of the necessary information was entirely at their disposal, and the estimating staff had done for them exactly as they would have done for his firm in estimating for a ship, and on the results of which his firm would have been prepared to take a contract without any hesitation whatever. The data given in the paper was the result of their calculations got up exactly in that way. He thought it due to them to say this, and also to his firm. He was just as free to discuss the paper as any member of the Institution.

Mr. A. McGLASHAN thought that Messrs. Jordan and Marlborough were to be highly complimented upon the nature of their paper, because of its valuable and interesting contents. It was a well packed paper, which a cursory reading did not enable one to fully appreciate. He therefore did not pretend to give an exhaustive criticism of it. In the main, he thought, he must agree with it, though points here and there in it might be discussed more fully, and some of them slightly changed in complexion. During the previous speaker's (Mr. Sivewright's) remarks he made a few jottings, and before they passed from memory he would like to say a few words on them. He (Mr. McGlashan) thought it was possible to overstate the difficulties that shipbuilders had to face in connection with the constantly varying rules and demands with which they had to comply. For instance, in the matter of spar-deck ships being loaded deeper and deeper and approaching more nearly to the loading of vessels of the three-deck type. He rather differed from the views expressed by the previous speaker, because first of all it would be well within the memory of the members that in the framing of the freeboard tables the three-decked vessel was allowed to be immersed as deeply as it was considered possible to immerse a vessel and retain sufficient height of platform for safety; and the freeboard was accordingly fixed to retain a certain minimum of reserve buoyancy above water as the basis of the load-line. On the other hand, the spar-deck vessel had much more reserve buoyancy, because the weaker nature of her top sides required a larger amount to be left above water in order that the vessel might not be loaded beyond her strength. And he saw no harm if a purely

spar-deck vessel requiring so much freeboard was found to have too much internal capacity for the deadweight carried, in making her stronger and loading her deeper to meet particular requirements. He thought it was quite right that deeper loading should be allowed in spar-decked vessels having poop, bridge, and forecastle; indeed, everyone would agree that if it was not for the cost of these erections no ship would be sent to sea without them, and he thought, as far as possible, encouragement should be given to fit them. He differed from Mr. Sivewright's view that the "Isabella" finding, as it was called, was a proper interpretation of the tonnage laws. These laws were not the work of yesterday, they had long been the basis for regulating port and other charges which had become adjusted to them, and it was impossible to bring in a new decision of this character without affecting unfairly the different interests involved. He thought, however, encouragement should be given to build large and airy places for the crew, and that was partly provided at present in having such spaces deducted from the tonnage. He was hardly able to accept the important proposition that ships should not pay any dues, and that all the dues should be paid by the goods carried instead. That was so far reaching a change, if adopted, that everything connected with the subject would have to be started anew. If the ships paid in the first instance, the goods must ultimately pay, and he (Mr. McGlashan) did not see that it mattered much which paid. Ships must have accommodation when loading and discharging goods, and often when they are loading and discharging little or no goods, and he thought it would be unfair that they should have accommodation without payment. He fancied it was rather a slip of the previous speaker to say a foot of depth could be built as cheaply as a foot of beam.

Mr. SIVEWRIGHT—Under certain circumstances.

Mr. MCGLASHAN—For instance, 1 foot of depth adds 2 to the frame numerals in Lloyd's tables, whereas 1 foot of beam adds only 1, and the increase in the plating numeral is in proportion. Independent of this, however, a foot of depth is likely to cost more than a foot of beam. But while saying that he would not be understood as agreeing that increase of beam was the cheapest way to increase capacity. He was not for a free hand in tonnage and freeboard. He thought it was a help to shipowners and shipbuilders, after all the troubles they had encountered, that the freeboard question had been settled on something of a satisfactory basis, and while the tonnage laws might be altered to bear more evenly on certain vessels according to their earning powers, he did not

think they could have anything better than the measure of internal capacity as the ruling factor. It just occurred to him that one explanation of the increased cost of the smaller spar-deck boats, referred to by the previous speaker, might be found in the fact that they had more freeboard in proportion to draught than the larger vessels had. This was because of the height from main to spar-deck being usually the same in a small vessel as in a large one. For instance, in a small vessel of 21 feet depth, 7 feet or 33 per cent. would be between decks, and in a larger vessel of 28 feet depth, 7 feet or only 25 per cent. would be between decks. And as the hull is of full scantlings to the main-deck only and of lighter scantlings above it, and the load-line is fixed largely in relation to the full scantling portion of the hull, the proportion above board is greatest in the smaller boats, and makes them cost more in proportion to deadweight capacity than the larger vessels do. It may here be pointed out that this also explains what the writers of the paper think is an anomaly in the freeboard tables, as shown in their table of freeboard percentages of moulded depth. Then in the matter of coefficients, in reference to what had been said and also in looking through the paper he felt they were confessing themselves somewhat helpless. He thought it was hardly reasonable or to the credit of the members of this Institution to declare themselves incapable of dealing with the fulness or fineness of models. There seemed a hankering in some quarters after a regulation or rule for coefficients. He would like to know where they would have been if the ideas of say five-and-twenty years ago had been fixed in some official way, and the very sharp models then in vogue carried down to the present day. The shipping community would not have the benefit they had from increased fulness; and although some vessels are built too full, he did not think they were the worst offenders in West Hartlepool, at least judging by the statements in the paper; he did not know how they would take to ·68, ·70, and ·72 as coefficients for ordinary cargo boats. He thought a great deal of useful experience had been gained by the growing fulness, which had, perhaps, now reached its limit. There were a number of vessels built about twenty years ago with round body and thin, hollow ends. They were poor carriers and not better sea-boats than the full boats that are said to have no ends at all, and some of them were lengthened by the insertion of a parallel midship body to improve them. He thought they had gained much by the question being an open one, and they better not seek to have tied hands in regard to coefficients, while asking free hands in matters of tonnage and freeboard. He

supposed that the difficulties encountered by the writers of the paper in trying to carry out fully the intentions conveyed in the title of it were felt to be rather large; because they were to have types and proportions in mercantile steamers. They had three types, but the proportions were all the same. In this he did not find fault with the paper, but it would greatly increase its value if they had on one hand a short boat and on the other a long one of each type placed before them, showing the effects of different proportions. One speed had been adhered to throughout, and that was valuable; but greater value might be found from a comparison of speeds of say 9 and 10 knots with the 9½ knots in the paper, because difficulty was sometimes experienced in fixing whether the horse-power was to be 900 or 1,000 for a particular ship, and what gain was to be expected by adding 100 horse-power. He thought the limit in future of the size of partial awning-deck vessels would be somewhere about 4,500 tons deadweight. A new rule was coming into force, which he thought wise as providing necessary strength, requiring the awning-deck in larger vessels to be carried to the after half length. This would make them double-decked ships throughout the greater portion of their length, and add to their cost, so that they would have few advantages not already possessed by the pure awning-deck or the spar-deck types. It was said in the paper it had been found advisable to fit 'tween decks to these vessels when of 4,500 tons capacity. Well, he did not know whether it had been found advisable as a question of having double-decks, but it had been found a necessity to have more internal capacity, hence the growth of this partial awning-deck type. It was not exactly an improvement of the old type, there was a demand for some kind of vessel having internal capacity somewhere between the spar-decker and three-decker, so as to suit the general requirements of trade. In small vessels there had been no difficulty for want of internal capacity, because the weight of the ship, machinery, and equipment was proportionately large to the size of the ship. He thought the writers were quite correct where they said "In the case of spar-deck vessels an improvement can be made which will not increase their cost of production, and will make them very much stronger than they are at present. This can be done by having the increased scantling of the sheer and stringer plates at the spar instead of the main-deck height," and so on. A great many vessels with continuous erections of a light character showed weakness in their top sides. The great mistake, hitherto, was in not transferring strength up to the parts which took the most strains. They were told

"Lloyd's rules practically fixed the weight of a vessel and therefore the cost." Well, Lloyd's rules in one sense fixed the weight of the vessel, but not altogether; for instance, if they had a ship with a poop, bridge, forecastle, or quarter-deck, then Lloyd's rules applied to these and fixed the scantlings; but Lloyd's rules did not, in most cases, fix whether there was to be a poop, bridge, forecastle, or raised quarter-deck. If there was to be a double bottom fitted, then Lloyd's rules applied to it, and scantlings and weight were fixed; but they did not provide that a ballast tank must be fitted. The weight and cost went up according to the requirements of the shipowners and trade, and Lloyd's rules were certainly responsible for the efficiency of whatever form was adopted, but they could not be saddled with fixing this, that, and everything. Then, again, it was said that "with a compulsory load-line, the carrying powers are limited;" but the carrying powers were always limited, whether by compulsory load-line or one of free choice. Sometimes the load-line freely chosen gave less deadweight capacity than the compulsory load-line afterwards allowed, and while it is admitted that the compulsory load-line generally allows less deadweight capacity, yet in some cases it gave more. Now, the fixed load-line gave a definite draught of water for a given ship; but that did not altogether limit the carrying capacity, for they had great scope in choosing the co-efficient of displacement, and he hoped they would continue to have it. It would be a pity if shipowners were to be tied to any particular model, or limited in what were really experiments for finding out which was the best ship. The modelling of ships was a fascinating subject, because it was not fully mastered yet. He thought there was a growing demand for vessels of bigger carrying capacity with shallower draughts. A consideration of page 282 and some of those following, would convince them that there was a good deal of truth in the statement once enunciated, that a great part of the business of the naval architect was to manipulate Lloyd's rules. If Lloyd's would take a hint, and judiciously vary the grades in the different tables so that less would be gained by working to certain numerals, there would be less necessity for this trimming of dimensions to get them not to exceed a certain scantling number. He would like to know whether in taking a partial awning-decker's capacity, it was considered right to take the whole capacity for a homogeneous cargo without regard to the effect on the trim? It seemed to him if 54·8 cubic feet per ton gave the density of the cargo filling the whole space in this type of vessel, something should be deducted, because, with homogeneous cargoes, these vessels required some space left empty forward to get an

even keel trim. Then, again, in the matter of bunkers, he thought in giving quantities of internal capacity, the bunker capacity ought to be estimated so as to leave exactly the 13 per cent. of tonnage required in the engine room, and the bunker and hold capacities treated as a whole. That would put all the ships on a fair basis of comparison. In the matter of co-efficients, he thought something more ought to be kept in view. These tables appeared to be based on having for all the ships a coefficient of ·78. Small vessels could not bear such a large coefficient as large vessels; a vessel of 3,000 tons might have a coefficient of ·77, a larger vessel of ·78, while in a vessel of 5,000 tons it might possibly be ·79, because, naturally, the length of the ends, or entrance and run, of vessels should be proportioned to their speed, and one coefficient should not rule every size of vessel for the same speed.

The PRESIDENT said he had spoken to Mr. Jordan about one or two things that Mr. McGlashan had said would add to the importance of the paper, although he did not see that an improvement could be made in regard to the question of speed. Perhaps Mr. McGlashan might find time to give them a paper dealing with extreme proportions and varying speeds, which would be a useful addition to the present paper. The question of bunker capacity would make the paper more valuable. Another thing that struck him would make the paper more interesting was a rough sketch of each of the types dealt with, showing the erections. This would qualify some of the statements made in the paper, and would make it of more commercial value, and they would be added to the final publication.

Mr. F. YEOMAN said that having waded a little through the freeboard question this paper had some interest for him, and one thing that struck him in connection with it was the apparent change gradually taking place. Mr. McGlashan had spoken about experimenting. It occurred to him they must be experimenting still, for he hardly knew whether he was awake or not when a vessel could carry, according to Table I., upwards of 3,200 tons deadweight, with 1 feet 4½ inches freeboard, when he remembered that ten years ago 2 feet 7 inches freeboard was required for a withal similar vessel carrying about 2,200 tons. The discussion of questions of this kind was of the utmost importance both to shipbuilders and shipowners, but especially was it so at a moment like the present. He had been busy that day with a memorial to the House of Commons asking the House to restrict the operation of the Employers' Liability Bill. By a single line in the Bill it was sought to make

the Act applicable to seamen, which it had never been before, and he did not forget that consequent upon an inch or two of freeboard, if this Bill passed as at present, some shipowner might be made liable to pay for twenty or thirty lives of his crew. He took it that a shipowner might be charged with the immersion of his ship through a captain or servant of his, and it would be useless longer to plead the safety of his ship. The shipowner, say, in the hands of a jury of farmers, would not have a chance, and he would be mulct in at least £4,000 or £5,000 because of the loss, as they would say, of an unsafe ship. That was the issue before them at that moment, and it was vital to shipowners and shipbuilders. He must say he was still rather jealous of the term "improved" well-deckers, which he noticed was again to the fore. One of the most important phases of this question, to his mind, was the fact that they had on the Tyne about 150 ships laid up, they had also about 50 ships laid up in the Hartlepools, and yet they had foreign ships running with practically no load-line incumbent upon them. He thought in that very port last week there was a ship loaded beyond which any similar British ship would have been allowed to proceed to sea. Foreign ships were often more deeply laden, more cheaply manned, and more cheaply provisioned, and as a consequence, the British shipowner had his vessels laid up, partly on account of the freeboard tables, but the foreigner did not lay up. He believed the freeboard question from its inception, from 1874 up to about 1885, when the battle was about through, took too much the style of a bribe—he meant a commercial bribe. The shipowner had not his freeboard given to the old ship because of its intrinsic merit. If he would fill up this and do the other he was allowed a reduction in freeboard, and he was compelled to do it. With a new ship on such and such lines, he could have lessened freeboard, and he took the new ship, not from conviction, but because they had more given them in the case of the new ships than they had in the old.

Mr. H. Macoll said this was a very elaborate and valuable paper. It would require a good deal of study to criticise it properly, and he had not been able to give it the amount of consideration it deserved; but he would be glad to say a word or two on the matter. The paper gave them the prevailing types of ships, and to a certain extent what they might expect in the near future. Unfortunately, there were so many ever-changing rules and regulations promulgated, often in the way of surprise, they resolved themselves very much into a question of wits between those who made the rules and those who—he would not say, who evaded them,

but who wished to enjoy the full benefit of them. Then the rules that were circulated now and then, by what they might call the "working department" of the Board of Trade, partook, he thought, very much of the nature of what was given as the definition of a scientific lecture—one fellow talking about what he does not know to people who do not understand him. One great question was the different descriptions of upper or weather-decks, which were being altered and modified in all directions, and it was getting to be a very difficult problem to decide what really was the proper definition of the upper-deck of some of the modern steamers—when, for instance, they were informed that the main or principal deck in a vessel is an imaginary line some 3, 4, or 5 feet below the actual deck in the vessel, and from this said imaginary line all the dimensions for scantlings, etc., are taken, and measurements for freeboard are based and more or less modified by the strength of the upper-deck, and then nearly all vessels are further complicated by the various styles of superstructures and deck erections. Now, they were told, while the enquiry was going on through the country some years ago, that the vessel without the forecastle would be looked upon with the very gravest suspicion. They were told distinctly unless they supplied a forecastle there would be very grave doubts of allowing the vessel to go to sea without a very considerable addition to the freeboard. So now, not many years after, a vessel with a forecastle and a bridge is the thing, and not a man-trap, to be put down. Fortunately, a ray of light had been thrown on the subject, and those structures known as well-decked ships had been accepted as something approaching to sea-worthiness, and not an unmitigated man-trap, as the official mind for so many years persisted in regarding them, and the well-decker continues to hold its own in comparison with all its numerous competitors. He had heard the word "improved" as applied to the well-decker—it was improving it very much out of existence, and they did not know exactly where they were. By way of retrospect, looking back a few years—say the seventies—in regard to a number of those celebrated ships then considered the acme of perfection, flush-deck ships, 280 × 35 × 25, those vessels would have been immensely improved had there been a well cut down some feet between the forecastle and front of the bridge, and with a higher working platform and lower centre of gravity of cargo, a number of these vessels would have been living now; but there was a craze for girder ships, giving a vessel deep continuous sides to form a girder, and it would be all right; but they became coffins. It was easy in criticising a paper to ask for further information; but really the writer of a paper could hardly

be expected to put a *vade mecum* of shipbuilding made easy into a paper. He thought the paper had been made very full, and deserved their warmest thanks—not only to the writers of the paper, but the shipbuilders who gave the information; so that they had not, like Oliver Twist, to go grumbling "we did not get more." With regard to the tonnage, he was certainly strongly of opinion that it was not right that any shipowner should be allowed to take off the tonnage of a ship what had not been first measured in the ship. The so-called "Isabella" question arose principally in reference to the above-deck casings round the machinery, and incidentally some portions of the crew space. The casings which had not been formerly measured and included in the tonnage were, under this decision, measured and deducted from the tonnage, and a considerable proportion of the above deck spaces occupied by the crew were deducted a second time from the tonnage. He did not think this was quite fair. They got vessels such as the "Isabella," which, by the way, was an Irish Channel paddle steamer, of considerable size, large value, high power, very little carrying capacity, and small tonnage. It would easily be seen how wrong it was to have such a vessel clearing off her liabilities to a dock company on the deadweight displacement basis.

Mr. SIVEWRIGHT—With reference to forecastle, not to displacement.

Mr. MACOLL—True. He understood Mr. Sivewright to desire or encourage the deadweight or cargo to be the basis. As to the proposal to make the coefficient of displacement the basis for the hull scantlings, he considered it was quite right and necessary that the coefficient should form one of the factors in the questions, but not the only one; certainly, as had been already said, the present system of classification scantlings gave far too great encouragement to the production of the very full lined vessel; they might carry the midship section right along to 10 feet from the bow and stern, and the midship scantlings remained the same, whilst a vessel of very fine lines, ·5 or ·6 coefficient would be burthened with the same midship scantlings. Spar-decked ships had been touched upon. He thought it was a very long time since he had seen a real, live, pure and simple spar-decker. Originally the spar-decker was a vessel which had a forecastle, long range of deck-houses, and possibly a poop aft, and when the roofs of these structures were made continuous, and the ship's sides run up to the top height, then they had the spar-decker a flush, unbroken upper-deck with only the hatches, companion, skylights, and low machinery casings, and such like appearing above the deck-line. Among the

earliest to favour this style of construction were Messrs. Allan, and a long discussion they had with the Board of Trade as to the measurement of these enclosed spaces, which were primarily used for the comfort and protection of the passengers and crew; but it was of no use if the spaces were measured in and added to the tonnage, and so all the owners got for the expenditure of a considerable amount of money in improving the vessels was to be fined in a large addition of dues in view of the additional tonnage. Another example of how this tonnage question works is seen in the two latest Cunarders, where almost two entire tiers of decks are left open at the sides, simply supported at the sides on stanchions. It is to be hoped that the passengers, when being driven across the Atlantic at a high speed, with a nice cool head wind, will thoroughly appreciate this outcome of the great desire of the Board of Trade to increase the tonnage of ships by all means in their power. However, this was getting away from the question. It was now over twenty-four years since he had to do with a real spar-decker, and in that case by stiffening up the sides and upper-deck she became, when completed, a three-decker, and he did not think he had seen since then an actual spar-decker. They had been getting forecastles, bridges, hoods, etc., and these, with stronger sides, got less freeboard; and more in virtue of these structures above the spar-deck, a further diminution of freeboard was granted, until the difference between a spar and three-decker came to very little. There could be little doubt that with the increased dimensions the ordinary cargo boat was assuming the advantages of the well-decker was steadily disappearing, and the advantages of the flush or continuous decker was getting more pronounced; and it seemed to him, now that a middle deck became imperative, one way out of the difficulty was to have the said middle deck made with the usual beams, stringer ties and hatches, and have the deck of wood and made portable. By this means the bulk cargo, corn, grain, ore, etc., could be loaded, and discharged with the advantage of having only one laid deck, and when goods liable to damage from weight or crushing, the wood deck could be laid in order to divide the cargo as might be necessary, and in boats of 4,000 or 5,000 tons he considered this would be a useful arrangement. No doubt the wood planks being portable would be liable to a process of disappearing, but so would any other property aboard ship if not well looked after. Several remarks had been made as to the load-line being now fixed. He ventured to dissent. It was not fixed, but it might be said to be defined. Take a three-decker, with an 80 feet bridge open at both ends. By the expenditure of a few pounds, the doors in the fore end could be closed up, and so obtain some inches more immersion.

Then another few pounds, to close up the after-doors, and a further diminution of freeboard was obtainable. When such trifling alterations can produce inches of alteration in the freeboard, it seems a misnomer to call the line a fixed one. But even apart from making any such alterations, he remembered the case of a vessel being stopped by the Board of Trade because, on account of a newly invented rule for freeing port area, the vessel was discovered to be unseaworthy by some 2 or 3 inches, and had to be lightened. Within three weeks after another set of rules were promulgated, and by this later arrangement the vessel was quite seaworthy, and did not require the additional freeboard. No doubt this vessel and many similar would be duly recorded and published to the world as one of the unseaworthy which were stopped and given in evidence as to the energy of the officials of the board, and the detriment of the owner. He quite agreed with Mr. McGlashan as to ships with light upper decks being employed carrying full cargoes of iron or ore, often showing weakness in the upper works. He had seen an Atlantic liner come into port with rents in her side from the upper deck down through the main sheerstrake, and a very considerable amount of strengthening was deemed necessary. It was much to be desired, that in high quarters, having, or being supposed to have, the welfare of the seafaring community under their care, an infusion of capable representative and responsible men were introduced, while it should be made a *sine qua non* that no new rules should be issued without first being submitted to a deliberative and responsible council of the various interests concerned. He was afraid his remarks were rather discursive. He now wished to record his appreciation of the paper before them, and hoped it would assist in bringing about that good time when they would have ships that pleased everybody, that never went wrong, and paid everybody all the way through.

Mr. W. H. Loveridge said the writers did not seem to take any notice in this paper of the web-frames, and did not say how much the introduction of web-frames was responsible for the inefficient carrying capacity of certain classes of ships. Lloyd's said they might build a vessel with web-frames and displace transverse bars, but they did not interfere with the stowage or condition of cargo. He thought the increasing of the beam without increasing the depth was getting very near a settlement of the question by the factor of safety coming in. It was a moot question where the White Star steamer, "Naronic," had gone; but it was also a question that if they increased their beam without depth while trying to increase capacity, they would have ships that

would roll over at sea. The large cargo boats were poaching on the work of the small vessels at the sacrifice of their sea-going qualities; but beam had about reached its limit. He would like to ask how much web-frames had affected the efficient cargo carrying capacity?

The PRESIDENT wished to try to define the spar-decker. He thought that in the case of those ships as they were now built the term spar-deck was really of no use. The name was in Lloyd's books, as when these vessels had the original character they represented there were certain defined rules formulated by Lloyd's to suit them. Now, the name was continued simply on that basis as a question of scantling. For instance, the spar-deck ship they had been speaking of was practically the old three-deck type, that was the form of them that had the poop, bridge, and forecastle; but slight reductions were made for scantlings as compared with the three-deck ship, and with the same erections as the original or flush-deck ship. Another type of vessel had been built by Mr. Laing, of Sunderland, and his (the President's) firm built one, they were called "semi-spar-deckers." How they came to have that title he did not know, except it was the qualification of thickness of plating and different scantling. This ship was built of the same dimensions, slightly reduced depth, with poop, bridge, and forecastle, but 'tween decks left out; and then came in the question raised by Mr. Yeoman. Lloyd's said to them, "If you put an iron 'tween-deck on that ship we will allow you 9 inches of freeboard." The question, then, was if a ship was allowed with a freeboard of 1 foot 8 inches, and the law said at 1 foot 7 inches, she was unsafe; it was not a definition of the load-line as they, practical shipbuilders and commercial men, understood it. It might be a reduction of the percentage of safety; but to say a ship was unsafe because she had 2 or 3 inches less freeboard than the rule allowed was simply ridiculous. Outsiders, no doubt, came to judge of the value of a ship in the same way as referred to in the paper, viz., the selling of a ship according to the deadweight. Indeed, a good deal of the capital of this coast had been invested here because one shipping company offered shares at £6 10s. per ton deadweight, another built a ship a little fuller for £6 5s., and the cheaper vessel was the one they invested in. These terms were very misleading to outsiders, and he quite agreed with Mr. Macoll that they should have some consultative body of experts at the Board of Trade, where these anomalies existed, they would then have a better basis to work upon. There was no doubt they simply progressed from one

thing to another. They had Acts of Parliament, but they had proved ineffective; but organisations throughout the country, bringing pressure on the Government, might get these things more easily balanced. In respect to the basis of scantlings he could give them no better result than this: if they built a ship 300 feet long and ·76 coefficient, and another on the same dimensions with a coefficient as high as what had been built, viz., ·82, the fuller vessel would carry 250 or 300 tons more than the finer. If they wanted the finer ship to carry 300 tons more they would have to increase the dimensions and probably build her on a higher grade for scantlings, and she would, consequently, be a much dearer ship. He held that in these very full ships they were adding 300 tons more for the same scantlings, and doing away with the margin of strength; whereas they had to put the finer ship on a higher grade. That was why Lloyd's rules were wrong respecting scantlings, so far as tonnage measurement was concerned. Could anyone tell him why the chain locker of a ship should not be deducted from the gross tonnage? This was a big space to carry a cable, and yet the Board of Trade laws made no allowance for that space. Then if they came to times like these the freeboard question was an important one. The foreigner got hold of British ships and loaded them 2 or 3 inches deeper than the Britisher did, whose vessels in consequence were often laid up. While the foreign owner ran his ships all right and proved that the Board of Trade load-line was a very safe one, because the amount of loss of foreign vessels would bear that out. At the present time it was their duty as shipowners and shipbuilders to bring all these points before those who had an opportunity of taking them further, to endeavour to better their position and justify the opinion they held that they were capable of building a good safe ship without so much interference from outsiders. He would just like to say, in addition, with respect to these semi-awning-deck ships, where the load-line had been fixed, classification depending upon the lines, they had experience of foreigners going out of British ports 4 to 6 inches below it. He took an opportunity of calling the attention of the committee at one of their meetings in London to it, and he supposed instructions were sent round the ports, that where a ship's classification depended upon her freeboard, whether foreigner or British, they should take steps to stop them loading deeper. Where the classification did not depend upon freeboard the owner might load as he liked; but otherwise, even the foreigner if he attempted to go below that line would have the classification taken from him.

Mr. YEOMAN said they knew that when the question was put what was to be done with the old ships, the ready answer to-day was "sell them to the foreigner." Foreigners even residing among them bought their ships partly to load them deeper than the British shipowner was permitted to load, and they were allowed to do so with perfect impunity.

The PRESIDENT—That is perfectly correct.

The meeting at this stage was adjourned.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

NINTH SESSION, 1892-93.

PROCEEDINGS.

EIGHTH GENERAL MEETING OF THE SESSION, HELD IN THE LECTURE HALL OF THE SUBSCRIPTION LITERARY SOCIETY, SUNDERLAND, ON FRIDAY EVENING, APRIL 14TH, 1893.

ROBERT THOMPSON, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting, held in West Hartlepool, on March 18th, 1893, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. J. Gravell and H. Macoll to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Bell, William, Shipyard Manager, Camperdown Shipyard, Dundee, N.B.

Gordon, William Leslie, Superintendent Engineer, Invermark Terrace, Barnhill, Broughty Ferry, N.B.

Graham, William, Ship Draughtsman, Los Astilleros del Nervion, Bilbao, Spain.

Purvis, Fred. W., Assistant Shipyard Manager, 2, Cambridge Road, West Hartlepool.

Smith, Malden H., Ship Draughtsman, Los Astilleros del Nervion, Bilbao, Spain.

Thornton, James, Foreman Engineer to Great Western Dry Dock, Bristol; Pullington Villa, Cumberland Road, Bristol.

ASSOCIATE.

Cooper, Charles, Average Adjuster, Wellington Road, West Hartlepool.

GRADUATES.

Guest, Thomas, Ship Draughtsman, 4, Coxon Street, Sunderland.

Kennedy, Robert Sinclair, Apprentice Engineer, Foyle Street, Sunderland.

Lynn, John Robert Dent, Apprentice Engineer, 31, General Gordon Terrace, Sunderland.

NOMINATIONS FOR THE COUNCIL.

The PRESIDENT said that, in accordance with Article X. of the Constitution, the following gentlemen would retire from the Council :—President—Mr. Robert Thompson ; Vice-Presidents—Messrs. A. Coote, J. Dickinson, and W. Kilvington ; Councilmen—Messrs. C. Furness, M.P., M. Hill, A. Laing, J. F. Walliker, and T. Westgarth ; Hon. Treasurer—Mr. G. E. Macarthy.

In accordance with Bye-Law 11, he, on behalf of the Council, now nominated the following gentlemen, to be balloted for, to fill up the vacancies :—President—Mr. Robert Thompson ; Vice-Presidents (three to be elected)—Messrs. W. Kilvington, A. Laing, L. Rusden, H. F. Swan, and J. F. Walliker ; Councilmen (five to be elected)—Messrs. C. D. Doxford, E. W. De Rusett, H. Fownes, W. Hök, C. H. Reynolds, J. C. Stirzaker, F. Yeoman (Associate) ; Hon Treasurer—Mr. G. E. Macarthy.

He invited any other nominations from the meeting, but there being none, it was agreed on his motion that the names mentioned go to the ballot.

PROPOSED ALTERATION IN BYE-LAW 11.

Mr. H. MACOLL gave notice that at the Closing Business Meeting in May, he would move that in the following paragraph extracted from Bye-Law 11, the words "at least two" shall be expunged, and that the word *one* be inserted in their place :—"It shall nominate new names in the place of the retiring Members, and the number of nominations shall be, *at least, two* in excess of the number required in each section of the Council."

INVITATION BY THE LEEDS FORGE COMPANY.

The PRESIDENT intimated the receipt of the following letter, which, he said, would be interesting to the members :—

LEEDS FORGE, LEEDS,
April 11*th*, 1893.

John Duckitt, Esq.,
North-East Coast Institution of Engineers and Shipbuilders,
4, St. Nicholas' Buildings West, Newcastle-on-Tyne.

DEAR SIR,—With reference to the communications which our Newcastle representative, Mr. William Brown, has had with you recently, we shall be glad to have the favour of a visit from the members of the

North-East Coast Institution of Engineers and Shipbuilders upon a suitable occasion, when we will lay open to inspection the manufacturing operations which are conducted at our works. We would say, however, that our managing director intends to leave for America on or about May 3rd, and will not return before June 30th, so that we should like arrangements to be made for some time after the latter date.

Our managing director, Mr. Samson Fox, will be pleased to have the company of members at luncheon, at Grove House, Harrogate, not later than 12·30 on the date selected, after which the company will proceed to these works, which, we hope, will be found of interest.

If you will be good enough to signify your acceptance, and to indicate a day for the proposed visit, we will make the necessary arrangements accordingly.

With compliments, we are, dear Sir,
Yours faithfully,
For the Leeds Forge Company, Limited,
ERNEST GEARING.

The PRESIDENT said they were very much pleased to have such an invitation, and they had accepted it. They had an invitation to visit another works in the north-east district; but the Leeds Forge Co. were the first to ask them, and the Council felt they should accept their kind invitation. He was sure from what they saw at similar works last year they would be interested, and that a good many members would join them. The date would be fixed at the next Council meeting, and due notice sent to the members.

The discussion on Mr. L. Newitt's paper on "Ships' Electrical Fittings" was resumed.

The discussion on Messrs. Jordan and Marlborough's paper on "Types and Proportions of Mercantile Steamers" was resumed.

Mr. S. O. KENDALL read a paper on the "Strains of Tank Steamers."

ADJOURNED DISCUSSION ON MR. L. NEWITT'S PAPER ON "SHIPS' ELECTRICAL FITTINGS."

Mr. L. NEWITT, the author of the paper upon "Ships' Electrical Fittings," said that when it was read on February 21st, at the Durham College of Science, a specially designed, portable electric lamp was shown, and not being familiar with its working he made a statement which did not appear to be correct on working the instrument. To do justice, therefore, not only to the maker but to himself, he would take the opportunity of showing that the lamp was not only certain in its action but also that it was honest as before stated. The former error arose from a contact which had been hastily made, and which consequently failed. (Mr. Newitt proceeded to show how it would give readers in railway carriages half an hour's light for one penny, and if the battery was exhausted the penny was automatically returned.) He brought it before the Institution, he added, to show how it was possible to adapt a small combined battery and electric lamp for use in tanks of petroleum steamers and other places where explosive mixtures existed.

Mr. J. C. STIRZAKER said Mr. Newitt's paper had been a most interesting one, because it was a sort of *résumé* of the different methods of applying electrical power. It was especially interesting to members of that Institution, as it brought very forcibly before them the great advantages of electrical telegraphs over the ordinary mechanical telegraphs on board ship. He thought that was one of the most important points of the paper to the members of that Institution. He (Mr. Stirzaker) knew that engineers had a feeling that nothing was so certain in its action as the purely mechanical arrangement. He was not quite sure whether that feeling was justified. He was inclined to think the mechanical telegraph was just as likely to get out of order as the electrical one. It would be very interesting if Mr. Newitt could tell them what was the opinion of officers of Her Majesty's Navy as to the action of this electric telegraph. The officers of Her Majesty's Navy were very difficult people to please, and if they were satisfied with its working he thought they might take it for granted it was nearly perfect, and it might with advantage be adopted in the mercantile marine. He might

refer to the night sights exhibited at the meeting in the Durham College of Science, but they were so obviously good it would be only wasting time to make any remark upon them. There was one statement in Mr. Newitt's paper which he should like to criticise a little. He said when speaking of the application of electricity to heating rooms or for cooking purposes, "The question of cost of electrical heating compares very favourably with other systems." He (Mr. Stirzaker) thought this could scarcely be, and that if they would follow him in a few figures they would come to the same conclusion. Mr. Newitt said that "a pint of water could be boiled with an expenditure of two-fifths of an electrical horse-power." Now, two-fifths of an electrical horse-power cost about a third of a penny, at the rate at which electrical power was supplied by the Newcastle companies. On another page he proceeded to say, "the water consumption per E.H.P. per hour is found to be about 34 lbs. of water, converted into steam at 100 lbs. working pressure." Now, they all knew that to evaporate a pint of water took considerably more heat than to bring it to the boiling point. The latent heat of steam was roughly, say, 1,000 degs., so, he would be well within the mark, if he said that it took six times the heat to evaporate a pint of water which it took to bring it to the boiling point. Therefore 34 lbs. of water required to give an electrical horse-power, converted into steam, would require as much heat as six times 34, or 204 lbs. of water brought to the boiling point. Now 204 lbs. of water equalled 163 pints, and two-fifths of 163 pints was 65 pints. Therefore, in order to boil 1 pint of water by electrical power, they would use as much fuel as was necessary to boil 65 pints of water in the ordinary way. That was not economy. Let them look at this matter from a domestic point of view. A pailful of coals cost about a penny, and a pail might be said to hold two gallons. Now, according to Mr. Newitt, to boil a pint of water two-fifths of an electrical horse-power, which cost a third of a penny, was used. Therefore, to boil a gallon of water it would cost about 3d., to boil a pailful of water, or two gallons, about 6d. But a pailful of coal cost only a penny, therefore, six pailsful of coal would be required to boil one pailful of water by electrical power. He did not think that was economy, nor that anyone would be inclined to cook food by electricity, except it was for advertising purposes, or unless he was an electrical enthusiast. There was another statement in the paper which he did not quite understand. Mr. Newitt, referring to Messrs. Scott & Mountain's slow speed motor, said that they had invented a motor which reduced the speed by the introduction of a worm wheel, with a loss by friction of only 15 per cent.

That was an extraordinarily small loss, for worm wheels were very extravagant in friction. Taking the sketch of the worm wheel as roughly to scale, and deducing from it the coefficient of friction by the ordinary formula for screws, also assuming the loss at 15 per cent., he found the coefficient of friction ·018, or, roughly speaking, $\frac{2}{100}$ths. Now, with the best worm wheel he had ever been able to make, having the teeth hobbed so as perfectly to fit the worm, and working under the best conditions, well lubricated, the coefficient of friction was not less than ·07, or $\frac{7}{100}$, and, under ordinary conditions, it generally amounted to about $\frac{1}{10}$. It would be very instructive to know how the frictions are brought so low on this machine. He thought that even if the worm worked in a bath of oil the coefficient of friction would amount to more than $\frac{2}{100}$. He should like to thank Mr. Newitt for the instructive and interesting paper he had given them, and the great trouble he had taken to exhibit so varied a collection of electrical apparatus.

Mr. M. SANDISON remarked that nearly all he had to say had been appropriated by previous speakers. Mr. Newitt's paper was a very interesting and instructive one. If it had a fault it was that he had not gone sufficiently into detail. For instance, as Mr. Stirzaker pointed out, the economy of electric heating was dismissed by simply saying: "The question of cost of electrical heating compares very favourably with other systems." That statement was not, he thought, sufficient to satisfy practical men. Then there was the question of cooking, but that had already been discussed. Further on, Mr. Newitt referred to lighting compartments on board ship by means of one or two large incandescent lamps instead of a number of small ones. He quite agreed with him there. He had had experience in ships where the system had been adopted with very great success indeed. In regard to Mr. Newitt's comparison between mechanical and electrical telegraphs and other appliances, he thought he had put the case rather too strongly in favour of electrical gear. If the superior reliability of electrical appliances had been demonstrated in practice they might depend upon it that more of them would be fitted. Possibly, however, Mr. Newitt hit the nail on the head when he referred to the passing of marine engineers in electrical subjects. That would appear to be essential in order to make a thorough success of electrical fittings on board ship. Before sitting down he might mention a somewhat interesting electrical phenomenon that came within his own experience. One dark night on board ship a joint in the whistle pipe "gave out." This joint happened

to be made with wire gauze. He went up on deck to see this joint, and on going close to it he found that the ends of all the fine gauze wires, which projected slightly beyond the flange of the pipe, and through which the steam was blowing, were tipped with electric sparks, forming, as it were, a complete fringe of electric light round the flange of the pipe. This he took to be a practical example in a small way of the hydro-electric machine which Lord Armstrong experimented with many years ago. He left this with Mr. Newitt, who might possibly be able to utilise it in some way.

Mr. E. G. GEARING wished to say that the difficulty he had found with electrical appliances fitted to ships had been to keep the water out of them. He was speaking of three years ago, when he had about a dozen electrical fans up to 1 electrical horse-power each under his charge. Whenever there was bad weather they invariably had one or more of the fans stopped; they never could really keep the water out of the motors, and that was the great detriment and difficulty they had to contend with in a pretty extensive plant. To that extent it was very unsatisfactory, although, generally, the handiness of the system was remarkable. He would like to know what arrangements had recently been made to overcome this difficulty?

At this point the discussion was adjourned, the SECRETARY mentioning that Mr. W. C. Mountain, who intended to speak on the subject, had been called away. Mr. Newitt's reply would be taken at the next meeting.

ADJOURNED DISCUSSION ON MESSRS. JORDAN AND MARLBOROUGH'S PAPER ON "TYPES AND PROPORTIONS OF MERCANTILE STEAMERS."

Discussion was resumed on Messrs. Jordan and Marlborough's paper on "Types and Proportions of Mercantile Steamers," the following communications being first read by the SECRETARY :—

COMMUNICATION FROM MR. OTTO ULLSTRÖM.

DEAR MR. DUCKITT,

I thank you for the copy of Messrs. Jordan and Marlborough's paper on "Types and Proportions of Mercantile Steamers in relation to Cost, Carrying Capacity, and Speed," duly received.

I have looked through the same and think it a most excellent paper, and does great credit to the writers, as the information contained is both interesting and extremely valuable, not only to shipbuilders but shipowners, as well as all people interested in shipping.

As regards the tables of weight, etc., I find these coincide very nearly with my own experience.

The tendency of increase of the spar-deck type of vessel is a step in the right direction, as, for all-round purposes, this is undoubtedly one of the best types of ship.

The tendency now to increase the dimensions of ships must lead to the necessity of having 'tween-decks, and, these being a requirement, the spar-deck ship naturally comes to the front, as she is well adapted not only for general cargoes but for the cattle and emigrant trades, where a continuous deck is almost necessary. The writer's observations as to Lloyd's requirements for strengthening spar-deck ships about the main-deck I fully agree with, and have many times wondered why this extra strength is not put on at the spar-deck height, where it would be of far more service to the ship, than as done at present, where the strength is too near the neutral axis to add to the necessary and important fore and aft strength for which it is intended.

I also think that although allowance is now made for erections of a spar-deck vessel, the freeboard might without risk be further reduced,

especially if the upper structure was strengthened as suggested, As regards tonnage measurement, an improvement could, I think, be made in this either by calculating same by displacement to load-line, as advanced by the writers, or from the displacement up to weather-deck, or the deck from which the freeboard is set off.

The coefficient of this displacement, or some other indication of the fulness of a ship, should also be used by Lloyd's to regulate the scantlings of materials, and I cannot but agree with the writers in their criticisms on Lloyd's grades, which, by ignoring the fulness of a ship, are thus giving an undue favour to a box-shaped vessel.

I regret very much my inability to be present at the discussion of this paper, as undoubtedly the same would be very interesting and instructive.

I thank the writers for the valuable information brought forward.

Yours faithfully,

OTTO ULLSTRÖM.

COMMUNICATION FROM Mr. J. DENHOLM YOUNG.

DEAR MR. DUCKITT,

I am sorry that I cannot be at the meeting to-night to express my belief that not only shipbuilders but also shipowners and engineers will feel grateful to the writers of this paper for the able and masterly way in which they have laid open and systematised the subject before them. Such tables and diagrams as they have compiled cannot fail to be useful in many an emergency, especially to those who have not the experience of years to fall back upon. Perhaps we may be permitted to hope that when Messrs. Jordan and Marlborough have time they will extend their tables and diagrams in both directions, down to smaller and up to larger vessels. I believe that data of smaller vessels would be of considerable value, because a large number of ships are built between 200 and 280 feet long, to say nothing of that shoal of small fry occupying a corner of the market—our steam trawlers.

One cannot, however, but notice that the first two items in the title —cost and carrying capacity—bulk much more largely in the paper than the third, viz., speed. I suppose this cannot be due entirely to the unimportance of the subject, but partly rather to the lack of definite and classified information, which is often bemoaned, and which is referred to in the paper. But perhaps the writers will still see their way to tabulate speed results of normal and abnormal types of vessels, all of which come within the title of the paper.

Most people will agree with what has been said as to the extremely full models now too often seen; and the results found in practice, that a vessel with full ends compares badly with a finer boat when driving against a head sea, although the two vessels may have nearly equal resistances on a smooth water trial, can easily be anticipated by theory. For at low speeds and in smooth water the resistance is chiefly due to surface friction, while in driving against a head sea the angle of entrance of the water-lines is evidently an important factor. Now, take two vessels of the same length, one of ·75 coefficient and the other ·81. There may be only a difference of about 3 per cent. in the wetted surface, while there is about 30 per cent. increase in the sine of the mean angle of entrance, figures which account for and explain the comparative results on trial and at sea.

At the same time, it must be kept in mind that vessels of great length may appear fuller than they are, when judged by their coefficient of displacement. Take a vessel of 5 beams to a length and ·75 coefficient, lengthen her by introducing a parallel middle body until she is 7½ beams to a length, and her coefficient becomes ·83, yet her entrance angles are the same, and she is just as fit to meet the resistance of a head sea as when her coefficient was ·75. This is an extreme case, but when taken together with the fact that great actual length generally goes with a decrease in the ratio of beam to length, it will serve to modify the objection to some apparently full vessels—of course, not to all.

I cannot but think that the opinion of the writers regarding "the successful cargo boat of the future" requires to be very carefully guarded and limited. The question of "the most economical speed" has been attacked by Mr. W. J. Millar, C.E., and is referred to in a paper read by myself before this Institution two years ago.

Yours faithfully,

J. D. Young.

Mr. W. Hök said the object of the paper was, as far as he could gather, to compare the different types of ships now in favour, and to find out which type was the most advantageous and cheapest to build. The writers had compared three different types—the three-deck ship, the spar-deck ship, and the partial awning-deck ship. In doing this they had chosen several sizes of ships. The way they had chosen their dimensions was this—the dimensions of the partial awning-deck ship were chosen so as to make Lloyd's numerals come as close under a grade as possible; in the spar-deck ship and the three-deck ship, where they had kept the same

lengths and breadths as in the partial awning-deck ship, they let the numerals come on the grade anywhere just as they happened to come. This procedure favoured the part awning-deck ship in regard to weight. The writers showed in a table on page 282 that going from a grade to the next higher they had to add for the spar-deck vessel from 7 per cent. to 14 per cent. of material, dependent on the size of ship. As material was approximately 20 per cent. of the load displacement, it followed that by stepping from one grade to the next they had to add material amounting to from 1·4 to 2·8 per cent. of the load displacement. This would be the most unfavourable case when no displacement was added but only material, *i.e.*, when the numerals were just over the lower limit of the grade. If, now, instead of this, the numerals came just half-way between the limits of the grade, consequently if displacement was added simultaneously with material these previous ratios would be reduced to about ·7 to 1·4 per cent. of the load displacement and so on, showing that the weight of material per ton of load displacement depended on the position of the numerals on the grade. Consequently the partial awning-deck ships having their numerals just under the grade were favoured in respect to weight. Another instance of how the partial awning-deck ships were favoured was that their 'tween-decks were 6 feet 9 inches, and those of the spar-deck ships 7 feet. That affected the weights, the tonnage, and the freeboard, and was all favouring the partial awning-deck ships. It would have been most interesting if the opposite course had been pursued too, and everything had been chosen so as to favour the spar-deck steamer. He thought the only correct way of comparing ships was the weight of material per ton of load displacement for some standard coefficient of fineness. Coming to the estimates, he thought that the weight of material in the partial awning-deck ships was as near as possible correct. The weights of the spar-deck ships were, he thought, too heavy by something like 1 per cent. of the load displacement. If they looked up the tables of weights their President so generously gave them in his address they would find that there was not that difference in weight of material between the spar-deck ship, the partial awning-deck ship, and the three-deck ship, as the writers had made out in their estimates. If all modern ships in these tables were reduced to the same fineness, ·78, that is, ships built after the last addition to Lloyd's rules (*i.e.*, 1890), they would find the weight of material per ton of load displacement would be about the same in them all. They would find that the weight of material in the partial awning-deck ship varied from 19·9 to 20·4 per cent.; in the spar-deck, from 19·9 to 20·4 per cent.; and in the

three-deck was 20·1 per cent.; thus all types were practically the same weight. After the authors had estimated the weights of their ships they had worked out the difference in cost, and found that it was cheaper to build a partial awning-deck ship than either a spar or a three-deck ship. No doubt there was a difference, and in regard to small ships the partial awning-deck ship was cheaper; but what he wanted to make clear was that the difference was not so great between the partial awning-deck and the spar-deck ship as the writers made out. And the size of ship when it would actually be cheaper to build a spar-deck ship would sooner be reached, say, at about 3,800 to 4,000 tons carrying capacity than what the writers made out in their paper. Of course, everybody was bound to admit that there was something in the partial awning-deck ship, for, if not, she would not be built; but he thought if they considered the way Lloyd's were daily reducing the freeboards of the spar-deck ships, that some day they would find that the partial awning-deck ships would have great difficulty in holding their own, especially as there was no more any reason for fitting raised quarter-decks, as they did no longer serve the purpose for which they were originated, viz., trimming ships by the stern. So he expected to see the partial awning-deck ship gradually disappear. And the table on page 276 seemed to support his view. He had manipulated the figures differently to the writers of the paper, and found that if they added all the ships together which had no break and the ships together that had a break for the years 1890, 1891, and 1892, ships with breaks were gradually disappearing. The figures for 1890 showed that ships built without breaks were 44 per cent. and with breaks 56 per cent. of the total number, being 12 per cent. in favour of the break. In 1891 there were 52 per cent. without breaks and 48 per cent. with breaks, and in 1892 there were 54 per cent. built without breaks and 46 per cent. with breaks, showing an increase in the three years of 10 per cent. of the total number of vessels built without breaks, and consequently a decrease of 10 per cent. of steamers with breaks, which showed that his view that ships with breaks were gradually disappearing, was supported by unimpeachable statistics. In conclusion, he thanked the writers for their paper; and although he could not entirely agree with all they had said, especially in regard to the important comparison between the different types of steamers now building, he had much pleasure in saying that the paper contained many valuable points and much useful information, for which he begged to thank them.

Mr. G. F. MULHERION said he viewed the paper as a most welcome addition to their Transactions. He complimented the authors for the most able, exhaustive, and suggestive work that had been given for some time in his own particular line. He must also congratulate the firm with which they served for their broad-mindedness in permitting such information to be made public. There was, no doubt, a great want of uniformity of ideas in the rising generation of the profession, and this paper would help to fix their minds and help them to form some relative idea of the interests at stake in their designing of ships. He had therefore very great pleasure in complimenting the firm that had made this information public. There were one or two points he would like to speak upon, not as one having authority, or having particular knowledge of costs, etc., but more as an outsider, more how it might strike, say, a shipowner, or the general body of the members. Of course, those versed in costs had their own ideas, which, he believed, it would be very difficult to move, and they had their own standards before them, but the general body of the members looked upon the paper in the light it was given there. Let them look at one or two of the vessels given. If they took No. 6 of the partial awning-deck type and compared it with No. 19, which was a three-deck vessel, they were the same length, breadth, and draught, and practically the same deadweight. They were told by the writers that the difference in cost of these vessels was that the three-decker cost 1·88 per cent. more than the partial awning-decker. He supposed this difference they might take to represent anything between £500 and £600 in the present day—each builder having his own idea what 1·88 per cent. was worth; but let them say it was worth £500 and what did they find? In each case the machinery was exactly the same, therefore the same cost; in each case the equipment was the same, therefore the same cost. He was speaking broadly and not entering into minor details; but they found, in the three-deck boat, they got 6 tons more of material, and that was the whole of the difference. To make the shipowner pay £500 for 6 tons of material was "coming it strong." Doubtless it might be pointed out there was another item of cost not detailed here, the labour; but on one of the pages the writers said: "Lloyd's rules practically fix the weight of a vessel, and therefore the cost," and that, to a considerable extent, was true, so that in the paper the writers evidently did not admit the item of labour, as affecting costs apart from material. If they followed out the same line of reasoning with No. 5, comparing it with No. 18, it was not so glaring, but still it did show palpably, and when he saw the figures his first feeling was to ask if they were correct, for to an outsider they did not seem as if

they were. When they got to smaller sizes there was a greater agreement with one's general impressions. Then, also, they had to consider the difficulty, as the writers pointed out, that when getting the same size of vessel in a different type, they ran into differences of all sorts of things. He had known where a three-decker was cheaper than a spar-decked vessel, but these exceptions proved the rule. It was impossible, he considered, to lay down any fast rule that would say any particular type had a certain percentage above the other type. In the olden days there were in the various grades weighty differences; in the present rules, if they got Lloyd's in one thing, Lloyd's got them in another, and this paper, he said, was a splendid testimonial to the fact. One of the Past-Presidents once said "how could a beam broken in the centre and then overlapped be as perfect as a beam that was unbroken," and for that, as well as other reasons, the vote, he thought, must be with the spar-deck vessel as being a more perfect vessel than the partial awning-decker. The last speaker (Mr. Hök) said that the spar-deck vessel could be 1 per cent. of the load displacement lighter than the figures there given; but he thought if Mr. Hök could get his vessel through at 1 per cent. lighter it was a great compliment to Mr. Hök, and he could only say he wished they were all in the same position.

The discussion was at this point adjourned.

STRAINS OF TANK STEAMERS.

By S. O. KENDALL.

[Read before the Institution, in Sunderland, April 14th, 1893.]

In submitting to the members of this Institution some observations on the construction of tank steamers, together with the results of an investigation into the strains to which tank steamers are subjected in performing the work for which they are designed, the writer feels that he is venturing upon a subject which is of exceptional difficulty and intricacy, but which at the same time offers a large and as yet comparatively untouched field for research, which it is to be feared is far beyond the scope of a single paper.

The writer's object in introducing this subject will, however, be fulfilled if he succeeds in drawing attention to and promoting the discussion of the more salient points in the construction of tank steamers and the latest development thereof: points which are at the present time exciting the liveliest interest in all connected with the shipbuilding trade and the mercantile marine.

A correspondent in a recent number of a popular shipping journal, writing on the subject of tank steamers, and the methods which have been pursued in their development, remarks :—"As a nation of working men we are nothing if not practical; we do not proceed on synthetic principles, but we dump cargo of any sort into a ship of any size and wait to see what happens."

It must be acknowledged that with regard to the development of the modern tanker the above remark contains a certain amount of truth, and looking back over the period of almost seven years which has elapsed since the first tank steamer successfully crossed the Atlantic with her 2,700 tons of American oil, one is surprised at the great increases which builders have been compelled to make in the scantlings of this class of boat in obedience to the demands of strains, which, although even now only imperfectly understood, manifested themselves in no uncertain fashion in the hulls of the earliest tank steamers.

For the benefit of those members who may not be conversant with the peculiarities in the construction of bulk-oil steamers, as compared with ordinary cargo steamers, it may be as well to touch briefly upon the special arrangements which are necessary in order to convey an oil cargo in bulk across any sea, in any weather, with the maximum safety to crew, ship, and cargo, and with the utmost economy and efficiency consistent with that safety.

The principal requirements in the design of a satisfactory tank steamer, may be generally summed up as four in number :—

1.—Safety from explosion or fire.

2.—Oil-tightness.

3.—Structural strength.

4.—Stability.

1.—*Safety.*—To guard against the danger of explosion of oil vapour, or gas, is by far the most important point to be considered, the numerous disasters of recent years bearing ample testimony to the truth of this statement. In order to secure the utmost safety for the oil it is usually deemed advisable to place the engines and boilers and galley right aft in the stern and to isolate them from the oil compartment by means of double coffer dam bulkheads; thus by adopting a system of electric lighting and heating by steam all fires are entirely removed from the proximity of the oil.

The danger from the oil itself is not nearly so great as might be supposed, and, as is well known, were a lighted taper thrust into a tank full of oil the liquid would not be ignited, no explosion would occur, and the taper itself would be at once extinguished.

The chief source of danger, however, is the explosive gases and vapours which are evolved from the oil, and especially from the crude material, which vapours remain in the holds after the oil has been pumped out. Of late years many devices have been introduced for getting rid of these vapours and gases, such as injecting steam into the oil holds, and exhausting the air through the ordinary oil suction pipes by means of a fan placed in the pump room. This method should be very efficient, as the oil vapour being about four times heavier than the air falls to the bottom of the hold and is thus drawn off first through the suction pipes.

The most dangerous oil for a vessel to carry is the crude natural petroleum as it comes from the wells; the reason for this is that it is composed of many different kinds of oils, some of them of an exceedingly volatile character, which at a comparatively low temperature give off a

highly inflammable vapour. In the process of refining these light, spirity oils, and also the heavy solid parts, called residuum, are removed, leaving a comparatively safe oil to be shipped for export, and so long as this oil is below a temperature of 76 degs. Fah. the amount of vapour given off is so slight as to be harmless provided efficient ventilation is maintained and proper expansion places provided.

With regard to expansion under heat it is a matter of great importance that trunks should be provided above the oil-deck in order to allow the oil to expand or contract, and at the same time keep the oil hold full. The bulk of oil is much more affected by heat than is water, for while water requires an increase of temperature amounting to 36 degs. Fah. to expand its bulk 1 per cent., ordinary American and Russian oil requires on an average only an increase of 21·5 degs. Fah. for a similar expansion, and in passing from the ice-bound ports of North America to the warm waters of the Gulf Stream an expansion of 2 per cent. might reasonably be experienced, and if sufficient space were not allowed serious leakage might be caused by the great pressure which would be put on the oil tanks.

The following table will show the principal properties of American and Russian oil :—

	American Oil.	Russian Oil.	Crude Oil.
Specific gravity at 60 degs. Fah.	·811	·824	·865
Cubic feet per ton	44·3	43·6	41·5
No. of degs. change of temperature to expand 1 per cent.	21·43	21·17	21·0
Lowest temperature at which an inflammable vapour is given off (degs. Fah.)	76°	82°	—

2.—*Oil-tightness.*—To ensure that the oil cargo will be retained within the spaces allotted to it, is a question which has a considerable influence on the structural arrangements of tank steamers. For convenience in pumping out and filling, the total oil space is divided by transverse bulkheads into a series of compartments, varying from 24 feet to 28 feet long, and each compartment is divided into two by a central longitudinal bulkhead.

At the extreme forward and after-ends of oil space double bulkheads are fitted, forming coffer dams, to prevent any leakage finding its way into the ends of the vessel and generating gas or vapour there.

If these coffer dams are filled with water the chance of leakage is reduced to a minimum, but it is doubtful if any shipowner would care to lose 200 tons deadweight for the additional security obtained.

The recent regulations with regard to the passing of tank steamers carrying oil in bulk through the Suez Canal have had considerable effect on the arrangements of these vessels; for whereas in many of the earlier tank steamers no coffer dam was fitted forward of the oil tanks, and the centre longitudinal bulkhead was not generally made oil-tight, the regulations now require a coffer dam to be placed at each end of the oil compartment, and the centre bulkhead is made oil-tight, to limit still further the size of each compartment, and recent vessels are almost all constructed to fulfil these requirements.

It will readily be seen that the oil-tightness of the transverse bulkheads is a most difficult point when the continuity of the stringers and keelsons is considered, and in all the early tank steamers and many of the later ones it was considered an essential point that no stringers or keelsons were to be carried through the bulkheads, but were to be cut and connected to them by bracket knees.

There is, in the writer's opinion, no serious difficulty in piercing the bulkheads in order to maintain the continuity of the stringers and keelsons, as experience has shown that when testing the tanks it is faulty rivets which give the trouble more than anything else. These leaky rivets are mostly the result of unfair holes, and on account of the difficulty in getting the rivet holes in a number of thicknesses of plates or bars exactly opposite each other, the builder who wishes to construct a satisfactory oil tank must adopt as his guiding rule "avoid three-ply." Many devices for carrying out this rule have been adopted by different builders, to detail which would be beyond the scope of the present paper.

Another rule which should also be observed as much as possible is to fit all connections metal to metal, and avoid the use of all felt, packing, or white lead as much as possible, as this is not only an inferior job to begin with, but the oil has a corrosive effect on these substances, and in time destroys them.

As regards the riveting of oil-tight seams, all laps subject to much pressure should be double riveted, and the maximum spacing should not exceed $3\frac{1}{2}$ diameters, and in stiffening angles and connecting bars which have to be caulked 4 diameters apart or 6 diameters apart if not caulked, all corner bars where subject to oil pressure should be double reel-riveted in each flange in place of fitting double bars.

The form of rivet which finds most favour in oil-tight work has a slightly countersunk head, which fills the ordinary drift of the punched hole; it is not so liable to leak under the head, and can be more easily caulked than the ordinary pan-headed rivet.

The amount of caulking which is required in an oil-tight bulkhead is very largely in excess of that required for an ordinary water-tight bulkhead, for not only seams, but all stiffeners and angles riveted to the bulkhead are thoroughly caulked, and the general practice is to caulk both sides of the bulkheads; although some builders have lately resorted to a one-sided caulk and have left the stiffeners uncaulked, and had satisfactory tests with this arrangement, but the double caulk gives very much greater security for a bulkhead which is subject to heavy pressure from either side. So heavy are the test pressures to which oil-tight bulkheads are subjected, that in spite of every care in riveting and caulking the white lead injector, although its use is to be condemned except where absolutely unavoidable, is an almost indispensable article in the testing of oil-tight corner bars, in order to fill up solid between plate and bar and thus prevent any spring under pressure.

In a recent case the test pressure on the transverse and longitudinal bulkheads was 45 feet head of water above the keel, equal to a pressure of 19·5 lbs. per square inch on the bottom plating; the size of the flat unsupported surface was equal to 23 feet by 29 feet, and the enormous strength of these bulkheads will be appreciated when it is stated that the maximum deflection under the above pressure did not exceed $\frac{1}{4}$ inch.

3.—*Strength.*—When the question of maintaining the longitudinal and transverse strength through all the oil-tight bulkheads and decks is raised, attention is naturally drawn to these parts of the structure as the most likely points for signs of weakness, and as a matter of experience it is at these interrupted parts that weakness has generally shown itself, in the form of loose and broken rivets. In considering the strength of a connection, composed entirely of rivets, considerable discount should be made for rivets which have had their strength impaired by passing through unfair holes, and also for the fact that in many cases where plates have to be screwed into place with considerable force before being riveted, the rivets are already in a state of local strain, and so are not so capable of bearing the general strains of the hull as they would be if the plates fitted fair before being riveted; and in the writer's opinion these points have much to do with the signs of weakness at bulkheads, where, according to calculation, the strength was fully made up.

By referring to Plate LIX., some idea of the extent of these riveted connections may be obtained. Figs. 1 and 2 show the riveting required by both Lloyd's and Bureau Veritas in the knees connecting the side stringers to transverse bulkheads in way of oil compartments. In a connection of this kind weakness shows itself principally in the rivets marked X X, Fig. 2,

connecting the stringers to the shell plating, and in consequence, double shell bars are usually fitted for about 6 feet on each side of the bulkhead, with rivets close spaced in each flange. The knee plates are about 6 feet by 6 feet, and are double riveted in the connecting angles to bulkheads.

The above arrangement was introduced by the Bureau Veritas Society, to whose enterprise we are indebted in a large measure for the development of the ocean tank steamer; it has been found to give every satisfaction, and is now insisted on by them. Lloyd's Society, following the lead of Bureau Veritas, recommend, although they do not insist on, the above method of bracket knee connection.

Fig. 3, Plate LIX., shows a portion of the riveting connecting a transverse bulkhead frame bar to the shell plating in way of an outside strake. For the purpose of avoiding three-ply riveting, a single broad flanged angle is used instead of the double angles usual in ordinary water-tight bulkheads, and for the same reason the bulkhead liners are only kept long enough to get one row of rivets on each side of the frame bar, this giving the additional advantage of allowing the liner to be caulked all round. By reference to the figure it will be seen that the shell is pierced all round by a double row of holes, spaced 3 inches to 3½ inches apart, through the transverse bulkhead frame bar; the short liners do not adequately compensate for this perforation on account of the close spacing of the rivet holes in their edge, necessary for caulking, so that, taking the weakest section of plating, as shown by the line B (Fig. 3, Plate LIX.), the line of fracture is very little removed from a straight line. These liners should have at least two rows of rivets each side of the frame bar with the inner row wide spaced, for it must be remembered that any failure in the shell plating would be disastrous in its effect, and would not give any of those premonitory symptoms which are observable in a strained butt or bracket knee connection.

Transverse strength has been and is still a source of continual trouble in tank steamers, not so much on account of the actual straining of parts, as from the nature of their design, the slightest working or racking seriously impairs the oil-tightness of the tanks. Fig. 1, Plate LX., shows a cross section through the 'tween-decks of an ordinary type of tank steamer. The expansion trunks are placed in the centre; and all frames are cut at the junction of the main-deck or tank top with the side of ship. On examination of this section it becomes evident that where heavy rolling takes place there will be a strong tendency for the top sides to rack or work, as they are simply planted on the main structure of the vessel, and as a matter of general experience this is what takes place, and

the rivets in the knees at the main-deck are often found to work slack, thereby causing serious leakage; the same defect is also found in the angles connecting the trunk sides to the deck, and no amount of caulking will stop these bars leaking when once they begin, because the root of the evil lies in the racking induced by heavy rolling.

The working of the side frames is only partially stopped by fitting large web-frames, W W (Fig. 1, Plate LX.), about 8 feet apart, and by increasing the size of the frame knees at main-deck.

The working of the trunk sides is, however, easily remedied by flanging the deck plates up to form the sides of the expansion trunks, thus dispensing with all seams at this point.

The above defects are entirely removed and many additional advantages obtained by a simple arrangement of the writer's, in which the expansion trunks are placed at the side of the ship as shown in Fig. 2, Plate LX.; by this means the frames may be carried in one length to the upper-deck, and the transverse bulkheads in the expansion trunks being at the sides act as webs for stiffening the top sides.

The centre bulkhead and all frame knees are entirely dispensed with in the 'tween-decks, giving a large open space in the centre, free of webs, capable of stowing a considerable amount of ordinary cargo, and which may be filled with coal with no risk of impairing the stability by uneven coaling, as in the case where the bunkers are placed at the sides. The saving in weight by this arrangement would amount to about 20 tons; while the work of construction is greatly expedited by being able to proceed with the top sides at once without having to wait for the frame tops to be erected. The sides of the expansion trunks are brought into the longitudinal strength by carefully shifting the butts clear of deck butts and treble riveting them.

The chance of leakage into the central space is reduced to a minimum, as there are no corner bars or angle iron connections under pressure. There is a slight additional exposure of the side, but this would not have an appreciable effect on the mass of the oil, and a simple means of ventilating the space over the surface of the oil would remove all danger.

The risk of loss of oil through collision is no greater than in a vessel of the type shown in Fig. 1, Plate LX., for a glance at the side will show that, by reason of the tumble home, the part below the main-deck would always be the first to receive the shock; so that the additional danger from this cause is more apparent than real. In addition, it may be added the level of the oil-deck in a shade-deck tank steamer is just about the level of the surface of the oil in Fig. 2, Plate LX.

Another weakness which has shown itself in many of the earlier tank steamers is a tendency to pant in the side stringers in way of the oil compartments—a tendency much in excess of that observed in ordinary cargo steamers. In the writer's opinion this is the result of want of uniformity in the rigidity of the structure; the transverse bulkheads, which might at first sight be supposed to be a source of strength in this respect, are in reality a source of weakness, as they deprive the vessel of all elasticity, and instead of an easy imperceptible spring, extending over a large area, we have severe local vibration, resulting in slack rivets and strained connections; so great is the effect of this panting, coupled with general straining, that there are several tank steamers which have had to be almost entirely re-riveted in the oil holds.

The original idea was that the increased number of transverse bulkheads would enable builders to dispense with web-frames or hold beams, but experience has shown that not only are web-frames as necessary but that a greater number should be fitted than if there were the usual number of bulkheads.

As an illustration of the great increases which have taken place in the hold stiffening of some tank steamers during a comparatively short period, attention is drawn to Figs. 1 to 5, Plate LXI., which represent midship sections in outline of five tank steamers built between the years 1888 and 1891, and are placed in order of date. Fig. 1, Plate LXI., is of slightly different dimensions but of similar design to the remaining four which are all of the same scrieve.

Fig. 1, Plate LXI., represents a cross section through the oil holds of a spar-deck steamer, 300 feet by 39 feet by 29 feet 3 inches moulded. The expansion trunks are continuous fore and aft, projecting 6 inches above the spar-deck, which is of wood. No webs are fitted in the oil holds, which average from 24 feet to 26 feet long each. Three side stringers are fitted 16 inches broad, measured from outside of frame, and on the middle stringer in the centre of each oil hold, a bulb plate beam is fitted with a vertical angle stay in line of trunk sides. All side stringers, keelsons, and centre bulkheads are cut at the transverse bulkheads, and the side stringers are connected to them by knees about 4 feet 6 inches long by 4 feet athwartships.

Fig. 2, Plate LXI., is a distinct improvement on its predecessor, being also spar-deck class, but having that deck of steel instead of wood, while the hold is further stiffened by the addition of a 16 inches web-frame in the centre of each oil hold; the remaining parts of the structure being of similar construction to Fig. 1, Plate LXI.

Fig. 3, Plate LXI., finds us advancing by a tentative process on the same lines as Fig. 2, Plate LXI.; the side stringers and web-frames being increased from 16 inches to 18 inches wide, while face angles are fitted on inner edge of stringer and carried along face of bracket knees at transverse bulkheads, the other parts remaining as before.

Fig. 4, Plate LXI., shows a distinct change in the method of hold stiffening; the hold beam is found to be unsatisfactory and is discarded, two 18 inches web-frames being fitted instead of one in each oil hold, equal to a spacing of 8 feet to 10 feet, while at the head of each web a strong beam is carried across on main-deck; when compared with Fig. 1, Plate LXI., this section appears very strong, both longitudinally and transversely.

Fig. 5, Plate LXI. It is evident from this figure that the required strength was far from being reached in Fig. 4, Plate LXI. The same point of weakness showing itself, viz., want of stiffness in the hold, and to meet this the side stringers and web-frames are again increased to 20 inches wide, while the stringer brackets at transverse bulkheads are increased from 4 feet 6 inches by 4 feet to 6 feet by 5 feet, and to stiffen the top sides webs are fitted in the 'tween-decks in way of oil compartment spaced 8 feet apart.

The above additions represent an increase of over 100 tons of material in the hull, and afford very fair evidence of the direction in which increases of strength have been required in tank steamers; and it may be added the more recent vessels of this class have had still further increases made in their scantling until the latest additions to our already large fleet of tank steamers may be said to have arrived by a tentative process to the standard of efficiency which is necessary in order to bear the heavy strains to which this class of steamer is subjected without showing those signs of weakness or fatigue which were evident in many of the pioneers of the bulk oil trade.

4.—*Stability* is a matter which requires the most careful attention of the designer of a tank steamer, for in his hands alone rests the question of the amount of stability which the vessel shall have when loaded with oil to her sea-going trim and draught, and to a large extent also the amount she will have when carrying ballast.

At the same time there is no doubt that if proper attention is given to this point in the design a tank steamer is one of the safest vessels afloat as regards stability.

In an ordinary cargo steamer the metacentric height is almost entirely in the hands of the stevedore, and is consequently an unknown or variable quantity notwithstanding the most careful calculations.

In the well-designed tank steamer, however, we have a constant and known quantity when loaded with oil, and a quantity only slightly variable under different dispositions of water ballast.

If the centre bulkhead is made oil-tight an additional security is obtained, especially when filling up or pumping out the tanks. Not long ago a tank steamer in which the centre bulkhead was not oil-tight had a narrow escape of capsizing through pumping out all the oil tanks, together with a high wind on the beam; when the oil got below the level of the deck the list due to the wind was aggravated by oil draining through the centre bulkhead until the inclination assumed such alarming proportions that further operations had to be suspended, and every effort directed to getting the vessel on even keel again.

A very common defect in the stability of tank steamers is that they have too great a metacentric height when in the loaded condition, and consequently great strains have been brought upon the hull by violent rolling, aggravating the racking tendency already mentioned.

In the writer's opinion from 1 foot to 18 inches is ample metacentric height in the loaded condition, while there are many tank steamers running now with 2 feet 6 inches to 3 feet G.M., and in some cases these figures are even exceeded.

Having thus generally reviewed some of the main features in the construction of tank steamers the writer now proposes to lay before the members of this Institution the results of an investigation into the various strains to which these vessels may be subjected in the course of their work.

The shade-deck type has been chosen for investigation on account of the interest which has been lately centred in this class of tank steamer, by reason of the opening of the Suez Canal to the passage of bulk-oil steamers, and also because in the shade-deck vessel, as represented in Fig. 1, Plate LXIII., the strains peculiar to tank steamers are found at a maximum, and thus afford an interesting case for examination.

Plate LXII. shows a cross section of the vessel through the oil holds, the scantlings of which are equivalent to the highest class both at Lloyd's and Bureau Veritas. It will be seen the oil is carried right up to the upper-deck with expansion trunks above, the main-deck is lowered to about midway between the upper-deck and bilge, and fitted intercostally between the transverse bulkheads, a feature which has been introduced in one of the latest additions to our fleet of tank steamers. By doing this an excellent stiffening is provided on the side at the point where it is most needed, though there is a disadvantage in lowering the neutral axis and

increasing the strains on upper works, a point which will be referred to later on. The engines and boilers have been placed aft, together with galley accommodation and all coal, the after and forward coffer dam bulkheads are carried to the shade-deck unpierced by any pipes, doors, or valves; under the engines and boilers water ballast tanks are fitted for trimming by stern, while the forepeak is also arranged for ballast. The pump room is placed amidships, in which position a more convenient arrangement of piping can be fitted.

In calculating the longitudinal strength of this steamer four conditions of loading have been taken as follows (Plates LXIII., LXIV., LXV., and LXVI.):—

A. Loaded with oil cargo and all coal.
B. Loaded with homogeneous ordinary cargo and all coal.
C. In ballast with three central oil compartments and peak tanks filled with water, all coal.
D. In ballast with alternate oil compartments and peak tanks filled with water, all coal.

In all four cases the bunkers have been taken as full, for as the coal is burnt out the after-tanks under the engine and boiler space are filled up for trimming purposes, thus the condition remains much the same when the coal is burnt out as far as weights are concerned.

Three cases have been worked out for each condition of loading:— First, when floating in still water; second, when floating on the crest of a wave her own length; third, when floating in the hollow of a similar wave.

The height of the wave is taken at 16 feet from hollow to crest, being a ratio of 21·69 to the length. For a wave of this length the maximum height which has been observed is about 20 feet, while a minimum of 9 feet is also recorded. The writer has been induced to take a moderate height from the fact that the calculation takes no account of the influence of wave structure, or the effect which variations of pressure due to wave formation have upon the buoyancy, and as at a draught of 23 feet this would cause considerable diminution in the bending moments a moderate height of wave would more correctly express the ultimate strains to which the vessel might be expected to be subjected. The effect of wave structure on the bending moments may be estimated when it is stated that a vessel floating among waves at a draught equal to about three-quarters the length of these waves experiences no perceptible change in the disposition of buoyancy by their movement past her hull, and the strains are practically the same as those in still water.

In each condition of loading the weight curves (Fig. 2, Plates LXIII. to LXVI.,) were calculated in the usual way by taking the weight per foot at different sections for the main framing, plating, beams, decks, etc., and running a curve through; then by adding the miscellaneous weights, cargo, ballast, etc., in the form of parallelograms representing by their area the total weight of each; having thus applied the whole of the weights for each condition, the area and centre of gravity was taken by Amsler's integrator, and found to correspond in each case with the displacement and position of centre of buoyancy due to draught and trim as previously calculated. The curves of buoyancy (Fig. 2, Plates LXIII. to LXVI.) were then run for the still water, wave crest and wave hollow positions, and the excesses of weight and buoyancy treated as a beam unequally loaded; the bending moments being obtained by integration in the usual manner for beams.

We will now examine each condition of loading and observe the effect upon the bending moments for all the three positions specified.

Condition A (Plate LXIII.) :—Loaded with oil cargo and all coal. In still water, as might be expected, we have a very considerable sagging moment of 35,500 foot-tons, due to the massing of the oil cargo in the centre. On the crest of a wave this is changed to a moderate hogging moment of 20,500 foot-tons, which acts at the after-end of the oil compartment, and is due to the weight of the engines and boilers and coal placed in the stern; though this moment is comparatively slight, it is succeeded, when in the hollow of a wave, by a sagging moment of 82,000 foot-tons, which is the greatest of its series. A glance at the curves of weight and buoyancy (Fig. 2, Plate LXIII.) shows that the very large excesses of weight in way of oil compartment and buoyancy at ends fully accounts for this moment.

Condition B (Plate LXIV.), loaded with homogeneous cargo, shows a marked change from the condition just examined, and the peculiar feature is the almost entire absence of bending moments in the still water position, while at the same time the hogging moments are increased to 41,200, and the sagging moments reduced to 50,400 foot-tons; but the sum of the hogging and sagging moments are much the same as in the previous case, being 102,500 for A, and 91,600 for B condition, a reduction of 10·6 per cent. only, from which we may infer generally that the sum of the hogging and sagging strains of a vessel in a sea-way are approximately the same for all conditions of loading, but the most favourable condition is when the two classes of moments are nearly equal, or are proportional to the resistance which the disposition of the material in the structure is capable of giving to compression or tension.

The ballast Conditions C and D, shown in Plates LXV. and LXVI., are a comparison of bending moments and strain under two different dispositions of water ballast.

It has been a vexed question whether a vessel is more severely strained by placing the ballast in alternate compartments, as in D, or by massing it all in the central compartments, as in C.

A circular issued by Lloyd's Committee in November, 1891, expresses in emphatic terms its objection to filling alternate compartments with water ballast, and recommends that the central adjacent compartments shall be filled; it is easy to understand that there is less local straining in this case, that is to say, there are fewer bulkheads under pressure, but how the general strains on the hull are reduced by such means is not so clear.

Referring to Condition C (Fig. 3, Plate LXV.), it will be seen that by massing the water ballast in the centre, a maximum sagging moment of 29,500 foot-tons is developed in still water; almost equal to the sagging which is experienced when loaded with a full cargo of oil.

The maximum moment on the wave crest is 30,500 foot-tons hogging, and takes place as in Condition A at the after-end of the oil compartment. In the hollow of a wave the vessel is subject to a sagging moment of 74,500 foot-tons, so that the condition is very much the same as when fully loaded with oil.

Comparing these results with those obtained for Condition D (Plate LXVI.), we find the 29,500 foot-tons sagging moment in still water reduced and changed to a slight hogging moment of 10,500 foot-tons at the extreme fore-end of the vessel; while the hogging moment on a wave crest is increased from 30,500 to 50,000 foot-tons; but the maximum sagging moment in the hollow of a wave is reduced from 74,500 to 43,000 foot-tons. A comparison of the curves of bending moments in the two figures shows at once that whereas the hogging and sagging moments are fairly evenly balanced in Condition D, the maximum sagging moments are greatly in excess in Condition C; but provided the vessel is sufficiently strong to withstand the extra strain due to concentrating the water ballast there is no doubt it is better for the bulkheads and local strength to do so.

The whole of the above results may be compared in Table I., page 344, together with the ratios to length and displacement, which formula is generally adopted for the purpose of measuring the comparative magnitude of bending moments.

The lowest ratio or worst condition appears to be Condition C in the

hollow of a wave = 32·5, while Condition A in the hollow of a wave = 34·4 is much the same. The above formula, however, is only useful in comparing moments at similar displacements; for displacement in itself is no measure of bending moments, and the greatest strain might be experienced at a comparatively light draught if the weights were disposed in a certain way.

Having ascertained the various maximum bending moments to which the tank steamer under consideration is subjected under different conditions of loading, it will now be necessary to see what resistance the vessel is capable of offering to the strains induced by these moments, in order to find the exact strain per square inch of sectional area on any specified part of the hull.

Table II. shows the comparative values of moment of inertia, and moment of resistance or $\frac{I}{y}$ where y is the distance of the part of section under consideration from the neutral axis, and I the moment of inertia.

Four different sections have been calculated as follows:—

1. Section in way of an oil-tight bulkhead.
2. Section in way of a web-frame in oil compartment.
3. Section at oil-tight bulkhead, but supposing the shade-deck to be removed.
4. Section at bulkhead with steel shade-deck.

In calculating the moment of inertia in way of an oil-tight bulkhead the line of weakest section in outside strakes was taken as shown in Fig. 3, Plate LIX., so that no account was taken of liners; in way of interrupted stringers the combined area of rivets through the horizontal flange of the angle connecting brackets to bulkheads was taken. For plates subject to tension ·27 of the gross area was deducted for loss due to rivet holes in way of oil-tight work, and ·17 in way of web-frames and ordinary work.

By reference to the midship section (Plate LXII.) it will be seen that there are two steel-decks, the upper and the main, the latter being intercostal between the transverse bulkheads as before stated; the centre longitudinal bulkhead is also intercostal, and the side stringers intercostal between web-frames. The shade-deck is of wood, except over the oil trunks, which part is of steel.

A comparison of sections 1 and 2, Table II., page 344, shows that the strength is fairly well made up in way of the bulkheads. The sectional area in each case being much the same. The moment of inertia is in excess in

No. 2 case, both for sagging and hogging, but owing to the neutral axis being so low, the moment of resistance is less on the upper works, and consequently the strains on this part, in way of web-frame, are slightly heavier than in way of bulkhead, though the strains on the bottom would be somewhat less.

No. 3 section, Table II., shows that there would be no loss of strength on the upper works if the shade-deck were removed altogether; for although the moment of inertia is considerably reduced, the moment of resistance on the upper-deck is much the same as it is on the shade-deck in the preceding sections, and, in addition the upper-deck stringer would be much more suited to take compressive strains with its beams spaced 2 feet apart, than would the thin shade-deck stringer with beams 4 feet apart.

It might be suggested to cut the shade-deck down at intervals in order to throw the strain direct on the upper-deck, but it is to be feared that serious working would then show itself in way of these breaks unless large doublings were fitted as in the case of a poop or bridge-end.

No. 4 section is intended to show the effect on the moment of inertia, etc., by fitting a steel shade-deck, say $\frac{6}{20}$ inch thick, and it will be seen it has a decided effect on the moment of resistance at shade-deck, increasing its value 17·6 per cent. for sagging, and 15·3 per cent. for hogging strains.

Turning now to a comparison of the strains shown in Table III., page 345, for Nos. 1, 2, 3, and 4 sections above indicated and for all the conditions of loading, we find for the No. 2 section in way of web-frame, that a maximum compression of 6·84 tons is experienced on the shade-deck stringer in A or loaded with oil condition in hollow of wave; if the shade-deck were not fitted, the strain on the upper-deck stringer would be 6·77 tons, while if a steel shade-deck were fitted the strain on shade-deck would be reduced to 5·82 tons; a reduction of 14·9 per cent. on No. 2 section.

The corresponding tensile strains on keel for the above conditions do not vary very much from the compressive strains. In No. 1 section we have a tension of 6·38 tons per square inch: this is reduced, however, in the section at web-frame No. 2 to 5·62 tons, on account of the heavy keelsons and greater area of shell plating. No. 3 section shows a large increase to 7·52 tons, so that it appears removing the shade-deck throws more strain on the bottom plating, while it leaves the upper works much the same. In the case of No. 4 section with steel shade-deck, we have a moderate tension of 6·11 tons.

As steel and iron, and more particularly steel and iron structures, are more capable of withstanding tensile than compressive strains, the former in a well-designed vessel should be in excess, but it will be seen that in sections Nos. 1 and 2 with wood shade-deck the latter are in excess at any rate in all cases where sagging is experienced; so from this we may conclude that it would be desirable to have more material on the upper works, which condition is more nearly approached in No. 4 section; and again, for a tank steamer with oil concentrated amidships, the material in the upper works should be disposed so as to resist compression particularly, while that in the lower part, independent of the strains due to fluid pressure, should be disposed so as to resist tension, for it will be seen from Table III. that whereas in No. 2 section the shade-deck stringer is called upon to withstand 6·84 tons compression, the keel plate has only to bear a maximum compressive strain of 3·03 tons; and, reducing the comparison to A and C conditions, the normal conditions of work, this figure becomes only 1·85 tons, little more than a still water strain; and, again, whereas the keel is subject to a maximum tension of 5·62 tons for No. 2 section at web-frame or 6·38 tons for No. 1 section at bulkhead, the deck has only a maximum of 2·87 tons when confining the comparison as before, and 4·71 tons taking all four conditions of loading.

The lowering of the main-deck is responsible to a certain extent for the excess of strain on the shade-deck, for if the main-deck were lifted up to the usual distance below the upper-deck the strains on the upper works would be reduced about 2 per cent., while those on the keel would be increased by a corresponding amount.

Reviewing generally the results in Table III. we find the strains, when loaded with oil and in the hollow of a wave, the condition which has just been dealt with in detail, are far the most severe, the only other condition in which strains of any magnitude would be experienced being the ballast Condition C in wave hollow, where a maximum of 6·22 tons compression on shade-deck stringer is reached; when this is compared with the wave hollow strain in Condition D, where the ballast is placed in alternate compartments, a marked reduction will be noticed, bringing the compressive strain on shade-deck down to 3·59 tons from 6·22; and the tensile strain down to 2·94 tons from 5·10, so that it is in this case an open question whether the general strength of the vessel should be sacrificed for the local strength of the bulkheads, or *vice versâ*.

The results which have just been submitted tend to show that, although the general structure of the shade-deck type of steamer taken for investigation would be amply strong to withstand the strains to

which it might be subjected, there would at the same time be a tendency to buckling and shirking which might cause local trouble. It would, however, be fairly met, as previously stated, by plating over the shade-deck, at least in way of oil compartment, while an intercostal girder between the shade-deck beams would be especially calculated to resist the severe compressive strains to which the upper works of most types of tank steamers, and especially the type just investigated, are to a great extent subjected.

The strains given in Table III., page 345, although approaching the limit of working safety, are not much in excess of those experienced by vessels loading iron ore or railway material, and it may be safely assumed that the peculiar loading of tank steamers is only slightly responsible for the severe strains to which they are subjected; although under certain circumstances the hull is taxed to the limit of working safety.

This being the case it is a matter of the greatest importance that no additional strains should be brought to bear on the vessel through the movement of oil or water in the tanks, and the practice of running up tanks in a sea-way or allowing loose oil or water to wash about cannot be too strongly condemned; there is no doubt that want of precaution in this matter, rather than structural weakness, has been responsible for a great deal of the excessive wear and tear in certain tank steamers; but with the experience which has been gained in the management as well as in the construction of vessels for carrying oil in bulk there is no doubt that later vessels of this class, though far from perfect, have reached a fair state of efficiency, and with careful handling should perform their heavy work with no more sign of fatigue than is usual in ordinary cargo steamers.

TABLE I.—SHOWING COMPARATIVE BENDING MOMENTS OF TANK STEAMER.

	Condition.	Position of Ship.	Maximum Bending Moments.	Character.	Displacement.	$\frac{D \times L}{M}$.
			Foot-tons.		Tons.	
A	Loaded with oil	still water	35,500	sag.	8,176	79·4
"	" "	wave crest	20,500	hog.	"	137·4
"	" "	wave hollow	82,000	sag.	"	34·4
B	Loaded with ordinary cargo...	still water	3,500	sag.	"	805·2
"	" " " ...	wave crest	41,200	hog.	"	68·4
"	" " " ...	wave hollow	50,400	sag.	"	55·9
C	Ballast in adjacent comprts.	still water	29,500	sag.	7,030	82·2
"	" " "	wave crest	30,500	hog.	"	79·5
"	" " "	wave hollow	74,500	sag.	"	32·5
D	Ballast in alternate comprts.	still water	10,500	sag.	6,841	224·8
"	" " "	wave crest	50,000	hog.	"	47·2
"	" " "	wave hollow	43,000	sag.	"	54·9

TABLE II.—SHOWING COMPARATIVE MOMENTS OF INERTIA AND RESISTANCE.

	1. Section in way of Oil-tight Bulkhead.		2. Section in way of Web-frame.		3. Section at Bulkhead without Shade-deck.		4. Section at Bulkhead after addition of Steel Shade-deck.	
	Sagging.	Hogging.	Sagging.	Hogging.	Sagging.	Hogging.	Sagging.	Hogging.
Sectional area in square inches ...	1,569	1,544	1,551	1,560	1,370	1,387	1,624	1,590
Moments of inertia	226,665	226,712	234,325	229,923	164,075	159,342	244,691	246,952
Neutral axis from shade-deck ...	17·98	20·81	19·56	21·67	Dist. from 13·54	Upper-dk. 16·69	17·37	20·19
Moment of resistance on shade-deck	12,606	10,894	11,984	10,609	On Upper-deck. 12,117	9,547	14,087	12,231
Neutral axis from keel	17·62	14·79	16·04	13·93	15·06	11·91	18·23	15·41
Moment of resistance on keel ...	12,864	15,328	14,608	16,505	10,894	13,378	13,422	16,025

TABLE III.—SHOWING COMPARATIVE STRAINS UNDER VARIOUS CONDITIONS OF LOADING.

	Condition.	Position of Ship.	1. Maximum Strains with Wood Shade-deck. Section at Bulkhead.				2. Maximum Strains with Wood Shade-deck. Section at Web-frame.				3. Maximum Strains without Shade-deck. Section at Bulkhead.				4. Maximum Strains with Steel Shade-deck. Section at Bulkhead.			
			Compression. Tons per Square Inch.	On	Tension. Tons per Square Inch.	On	Compression. Tons per Square Inch.	On	Tension. Tons per Square Inch.	On	Compression. Tons per Square Inch.	On	Tension. Tons per Square Inch.	On	Compression. Tons per Square Inch.	On	Tension. Tons per Square Inch.	On
A	Loaded with oil ...	still water...	2·81	deck	2·76	keel	2·96	deck	2·43	keel	2·93	deck	3·26	keel	2·52	deck	2·64	keel
"	" "	wave crest...	1·34	keel	1·88	deck	1·22	keel	1·93	deck	1·53	keel	2·25	deck	1·28	keel	1·68	deck
"	" "	wave hollow	6·50	deck	6·38	keel	6·84	deck	5·62	keel	6·77	deck	7·52	keel	5·82	deck	6·11	keel
B	Loaded with ordinary cargo ...	still water...	·28	deck	·27	keel	·29	deck	·24	keel	·29	deck	·32	keel	·25	deck	·26	keel
"	" "	wave crest...	2·68	keel	3·77	deck	2·50	keel	3·88	deck	3·08	keel	4·32	deck	2·57	keel	3·37	deck
"	" "	wave hollow	4·00	deck	3·92	keel	4·20	deck	3·45	keel	4·16	deck	4·62	keel	3·58	deck	3·75	keel
C	Ballast in adjacent compartments ...	still water...	2·34	deck	2·29	keel	2·46	deck	2·11	keel	2·43	deck	2·71	keel	2·09	deck	2·20	keel
"	" "	wave crest...	1·99	keel	2·80	deck	1·85	keel	2·87	deck	2·28	keel	3·19	deck	1·90	keel	2·49	deck
"	" "	wave hollow	5·91	deck	5·78	keel	6·22	deck	5·10	keel	6·14	deck	6·83	keel	5·29	deck	5·55	keel
D	Ballast in alternate compartments ...	still water...	·83	deck	·82	keel	·87	deck	·72	keel	·87	deck	·96	keel	·75	deck	·78	keel
"	" "	wave crest...	3·26	keel	4·58	deck	3·03	keel	4·71	deck	3·74	keel	5·24	deck	3·12	keel	4·09	deck
"	" "	wave hollow	3·41	deck	3·34	keel	3·59	deck	2·94	keel	3·55	deck	3·95	keel	3·05	deck	3·20	keel

The meeting terminated with the reading of the paper, discussion being held over till the next meeting.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

NINTH SESSION, 1892–93.

PROCEEDINGS.

NINTH GENERAL MEETING OF THE SESSION, HELD IN THE PHYSICAL LECTURE HALL OF THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-UPON-TYNE, ON TUESDAY EVENING, APRIL 18TH, 1893.

ROBERT THOMPSON, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting held in Sunderland, on April 14th, which were approved by the members present, and signed by the President.

The adjourned discussion on Mr. L. Newitt's paper on "Ships' Electrical Fittings" was concluded.

The discussion on Mr. S. O. Kendall's paper on 'Strains of Tank Steamers" was opened.

ADJOURNED DISCUSSION ON MR. L. NEWITT'S PAPER ON "SHIPS' ELECTRICAL FITTINGS."

Following up the discussion on Mr. Newitt's paper on "Ships' Electrical Fittings," the SECRETARY read the following communication from Mr. W. C. Mountain, of the firm of Messrs. Scott & Mountain, electrical engineers, Newcastle :—

COMMUNICATION FROM MR. W. C. MOUNTAIN.

DEAR MR. DUCKITT,

I regret that I have unfortunately been unable not only to attend the reading of the paper, but the discussions on both occasions, and therefore I am somewhat at a disadvantage in replying to the various comments that have been made by speakers on the question of worm gearing and electric motors for driving fans.

I think that the Institution is greatly indebted to Mr. Newitt for the very able manner in which he has laid before them the different applications of electricity to ship purposes, and I am sure that many members, including myself, have been greatly interested in the very clear and explicit way in which these various applications have been explained.

The question of efficiency of worm gearing is one which has for a long time had the serious consideration of many engineers, myself amongst the number. My first experience of worm gearing on a large scale was in its application to windlasses and capstans, my firm in Birmingham having built for Messrs. Harfield & Co. some of the largest windlasses afloat, and we found from experience with these windlasses that unless the worm gearing was well proportioned, and the teeth very accurately made, that the friction was enormous, and further, that one of the most important points was the lubrication.

When my firm obtained the contract from Messrs. G. B. & T. E. Forster for the electric pumping plant for North Seaton, the question of gearing was one to which I had to give serious consideration. My objection to spur gearing was that it occupied a very considerable amount of room, and that I had not had any experience in spur gearing, or at any rate satisfactory experience where the peripheral speed of the wheels was as high as 2,500 feet per minute. I do not see any difficulty in designing spur gearing for that speed or even a higher speed, assuming

that the gearing is very accurately made, or better still, that the pinion is made of either steel or wrought iron, carefully machined, and that a mortice wheel is used fitted with wood teeth, but even then the arrangement, involving, as it did, three pairs of wheels to get the reduction in speed was cumbersome, and after considerable discussion and consideration I decided to use worm gearing. I may state that before coming to this decision I asked several of my engineering friends, who all considered themselves authorities, whether they had had any experience in worm gearing, they all said that they had, and that it was unsatisfactory. When I asked them the reason why it was unsatisfactory, they said that generally they did not like worm gearing, and they avoided it when they could, and, therefore, their experience had only been small. I, however, finally decided to adopt this class of gear, and the gearing in the North Seaton pumps, which is illustrated in the paper, consists of a worm $5\frac{3}{4}$ inches diameter, double threaded, $3\frac{1}{2}$ pitch, made of case-hardened wrought iron gearing into a phosphor-bronze wheel, $26\frac{3}{4}$ inches diameter, fitted with 48 teeth $3\frac{1}{2}$ inches pitch, that is to say, the actual pitch between tooth to tooth is $1\frac{3}{4}$ inches. This gear was designed to transmit as a maximum 15 horse-power, and the pinion runs in a bath of oil, the worm wheel being covered with a sheet-steel case to prevent the oil being thrown off the wheel. This gear has run very satisfactorily since starting, nine months ago; in fact, only last week, I was informed by the colliery officials that the pumps had run for 144 hours without stopping, and that there was not the slightest sign of heating in the gear, and that during the whole of this time they had been transmitting fully 10 horse-power. I lay great stress upon the importance of making the wheel and the worm wheel of different materials, and for high speeds I am certainly inclined to recommend the use of case-hardened wrought iron and phosphor-bronze. Of course it is very necessary that the wheels should be very accurately made, and in order to ensure this result I made a steel hub exactly in the form of the worm, the steel hub being cut into teeth, so that it really forms a worm-cutter, and I recommend anybody wishing to make accurate worm gearing to adopt this plan, as it is quite impossible to make a true worm wheel by any other method.

As regards the efficiency of this gear I am sorry that I have not very much data by me, but the following data may probably be sufficiently accurate to show that the gearing is by no means inefficient, in fact, in my opinion, quite as efficient as the spur gearing would have been, taking into consideration that three sets of wheels would have been necessary to obtain the reduction in speed:—

Power given off by dynamo = 240 volts at 30 ampères, *i.e.*, 7,200 watts.

Deduct 1,989 watts = loss in cables 5,400 yards long of $\frac{7}{16}$ cable.

= 5,211 watts at motor.

5,211 watts at motor, taking the motor at 85 per cent. efficiency = 6 effective horse-power on motor spindle.

Water pumped = 250 gallons per minute against 50 feet head = 3·82 horse-power actual work done in the pumps, or a total efficiency between the effective horse-power on the motor spindle and the work in the pumps of 64 per cent.

It must, however, be borne in mind that these pumps are large, being fitted with three rams, 9 inches diameter and 15 inches stroke, and that the friction in the pumps themselves is considerable, and there is no doubt that the efficiency would be considerably higher if the pumps were working against a head of 100 or 150 feet, which they are capable of doing when occasion arises.

I may state that for lubricating purposes we use a mixture of thick oil and water, which forms a kind of soap, and we find that this works excellently, as there is no sign of cutting whatever.

I have recently applied worm gearing to electric capstans. In this case the gear was made with steel worm and cast iron worm wheel, and the result is also satisfactory. The lubrication we used in this instance being black lead and tallow.

Referring to the application of worm gearing to electric traction purposes, I think I cannot do better than refer to some valuable information on this subject given by Mr. Reckenzaun in his new work on *Electric Traction.* I may state that I obtained this book after the gearing for North Seaton had been designed, and it is gratifying to see that he so fully bears out my own opinions on the subject. Speaking of the efficiency of worm gearing, Mr. Reckenzaun makes the following statement respecting efficiency:—

"The valuable researches of Professors Thurston and Kimbal and Mr. Beauchamp Tower on the subject of friction and lubrication revealed the fact that the long established laws on friction were entirely wrong. The experiments of these scientists proved conclusively that the coefficient of friction varies with the velocity, and that it decreases up to certain limits, with an increase of speed between lubricated surfaces. It was also found that the coefficient of friction between the lubricated bearings is not ·1 or ·2 as so frequently stated in text-books, but 0·003 and

less, and that even with moderately bad lubrication it amounted to only 0·01.

All these and other considerations encouraged the author in the belief that there was a fruitful field for further investigation, and he designed in the year 1883 a set of worm gear of the following dimensions:—Steel worm, turned and polished, 6 inches in diameter, 6 inches long; treble thread of 6 inches pitch; worm wheel of phosphor-bronze; trimmed teeth, $15\frac{9}{32}$ inches in diameter, $3\frac{1}{2}$ inches face, 24 teeth; ratio of gear, 8 to 1.

When testing the gear the worm was fitted to the spindle of an electric motor and the worm wheel attached to the axle of a tramcar, which was supported on a frame with bearings to keep the wheels off the ground. When running empty with the worm out of gear the motor took 6 ampères, and when put in gear, but without any load, 7·75 ampères were used to drive the apparatus at the same speed. Prony brakes were then applied to both the motor shaft and the car axle, and the power was measured on each at a given electro-motive force, current, and speed. The efficiency of the gearing was calculated by dividing the horse-power given off on the axle by that measured on the worm shaft, and it was found to increase with the speed, viz., at 300 revolutions of the worm it gave 80 per cent., at 530 revolutions per minute 81·1 per cent., at 676 revolutions 85·1 per cent., and, finally, at 770 revolutions 87 per cent.

In the gearing, as at present constructed by the author, the worm is turned out of a solid piece of steel and perfectly polished; its diameter is 6 inches, and it has a treble thread 6 inches pitch. The phosphor-bronze worm wheel has its teeth thoroughly trimmed and polished inside; its diameter is $15\frac{1}{4}$ inches, and it has 24 teeth."

Later on Mr. Reckenzaun gives a further table as under, giving the actual results of efficiencies obtained with spur gearing and worm gearing:—

Gearing used.	Number of Revolutions of Armature.	Total Efficiency at Maximum Load in Per Cent.	Commercial Efficiency of Motors in Per Cent.
Double reduction spur gearing, speed ratio about 1 : 10 ...	1,100	60-65	75-85
Worm gearing, worm with double thread, speed ratio 1 : 14 ...	1,200	65-69	75-85
Single reduction, spur wheel gearing, speed ratio 1 : 4 or 5 ...	450	80-83	85-88
Gearless motor	110	82-85	82-85

Another point raised in the discussion by Mr. Gearing, was the application of electric motors to fans and other machinery on board ship, and his principal objection to electric motors appears to arise from the fact that in his experience the motors were liable to injury through wet, dust, dirt, etc. Recognising the importance of making a motor which should not have these objections, I designed about six months ago an electric motor, which is entirely encased, that is to say, the armature, commutator and brushes run in a box with a cover at the top, enabling the machine to be got at if required. The spindle runs through both ends of the box through either a water-tight gland or a bush sufficiently tight to meet the requirements of the special case for which the motor is being made. I may say in designing this motor the box was made so that it really forms part of the magnetic circuit, and therefore the motor itself is very little larger than an ordinary motor for the same output would be. I have applied this motor to an electric drill, the motor being made as described above, and I have no hesitation in stating that this motor can be used in an ordinary shipyard where rivets and pieces of iron are thrown about, and that it would run perfectly, and I hope very shortly to speak positively on these points.

I have further made an electric motor to be coupled direct to the spindle of a centrifugal pump; it is intended to use this motor in the open air, where it will be subjected not only to rain, but may probably be flooded, as it is proposed to use this combination for pumping out dry dock work, etc., the motor being simply slung by a chain and fitted with flexible suction and delivery pipes.

Calling attention for one moment to the special type of engine and dynamo illustrated in the paper, which I designed on behalf of my firm, some surprise may be expressed by members present at the use of a single cylinder engine. In the first instance, there is no doubt that a single cylinder engine is less complicated than a compound engine, and on board ship, where, I am sorry to say, electric lighting plants do not receive the most careful attention, the chief point is undoubtedly simplicity; the second point to be considered is the relative efficiencies of a compound *versus* a single cylinder engine, and I believe that if the all-round efficiency of a day's work were taken that a single cylinder engine would be no less economical than the compound, because it is a well-known fact that a compound engine, unless it is working up to as much as half its load, is most uneconomical, as the low pressure cylinder is doing no work, and has to be dragged round by the high pressure cylinder. I saw a practical example of this on board a passenger ship in the docks,

London. The engineer on board, who showed me the electric machinery, called my attention to the combined engine and dynamo, and upon my asking him why the high pressure cylinder was not being used, he informed me that when he worked the engine as a compound, he could not get the power out of it, he therefore decided to take the piston out of the high pressure cylinder, and disconnect the connecting rod and simply put a washer in the gland, with the result that the low pressure cylinder was then used. He informed me that the engine ran not only more economically, but far more satisfactorily than it did previously, and he did not intend to go back to the old arrangement.

Another point about the combination, however, and one which I consider is of great importance to ship work, is the design of the bed-plate. It will be noted that the engine, engine bed, dynamo bed, and extended bed-plate for the outer bearing, are in three separate castings, these key into each other, and are held together by turned bolts. The dynamo bed is made entirely of gun-metal. In any case it would have been necessary to have brass blocks underneath the magnets to insulate them from the bed-plate, so I decided to entirely dispense with these blocks and make the whole bed of brass, with the result that a very considerable decrease in weight is obtained without in any way weakening the combination. The plant illustrated is capable of giving an output of 400 ampères at an E.M.F. of 80 volts when running at a speed of 325 revolutions per minute, and can be got entirely through a hole 2 feet 6 inches square when taken to pieces.

The electric governor is a feature about this engine from which I hope to obtain excellent results. It must be borne in mind that it is not a constant speed of the engine that is to be obtained, but a constant E.M.F. at the dynamo terminals, and this can only be done by an electrical governor.

Yours faithfully,

W. C. MOUNTAIN.

MR. L. NEWITT'S REPLY.

Mr. L. NEWITT, in reply, said, on opening the discussion, Capt. Lloyd made some remarks with reference to the heating of cabins by electricity. It is very difficult to make a correct comparison between heating by electricity and ordinary fires. No figures taken on the basis of an electric supply company were of use in this case, because nearly all the central station expenses and laying of costly underground main

cables were done away with, and the very small amount of power required for this work on board ship, where so many thousands of horse-power were provided for, would scarcely be felt. However, taking a case like the following, some information was obtained. To warm a cabin, whose dimensions were 20 feet by 16 feet by 7 feet, 746 watts, or 1 E.H.P. would be ample. To obtain 1 E.H.P. per hour 34 lbs. of water would be consumed, and to evaporate 34 lbs. of water, approximately 5 lbs. of coal would be required. Coal at 16s. per ton would mean that they got 12 lbs. of coal for about 1d., thus for 1 E.H.P. per hour, coal would cost $\frac{5}{12}$d., and water wasted and oil used might be estimated at $\frac{1}{12}$d., *i.e.*, for ½d. per hour 1 E.H.P. was obtained without any of the inconveniences or dangers of a fire, as pointed out in the paper. Taking the ordinary fire, attendance, cleaning, and coals, might well be estimated at ½d. per hour, so that as stated in the paper, the cost of electrical heating compared very favourably with the ordinary fire. This comparison might by some be considered unfair, because attendance to electrical appliances was not included, but as pointed out no increase in the number of engineers would be necessary, and the engines and dynamos would only be increased in size to meet the further demand of power. Cooking with an electric oven of large size, 6 ampères at 100 volts are required for 30 minutes, when the highest temperature, viz., 400 degrees, is obtained, then 75 per cent. of the current is switched off, 25 per cent. being found ample to maintain the heat. Supposing this oven was used for domestic purposes, and that the electricity required costs 4½d. per unit (*i.e.*, 4½d. for 1,000 watts per hour) as charged by one of the Newcastle electric supply companies, and supposing the time required 3 hours. For the above, the cost of the current would be as follows:—

6 ampères, at 100 volts for 30 minutes, give 300 watt hours, which will cost	1·35d.
And 1½ ampères, at 100 volts for 2½ hours, give 375 watt hours, which will cost	1·68d.
	3·03d.

Adding these two amounts together it will be seen that this oven can be kept hot for 3 hours for a sum slightly exceeding 3d. Then, seeing that the current was switched off immediately it was not required, no waste went on as with an ordinary fire.

One other point raised by Mr. Stirzaker with reference to the boiling of water needed a little correction. 3 ampères, at 100 volts for 10 minutes, give 50 watt hours, and if 1,000 watts cost 4½d., 50 would cost $\frac{9}{40}$d. For continued heat this rate of cost would be considerably decreased.

The question of electric telegraphs, either as a stand-by for mechanical telegraphs or as substitutes, was an exceedingly important one. Amongst others, the Willans-Robinson telegraphs, as manufactured by Messrs. Elliott Bros., had been fitted into many of Her Majesty's ships, and the following short extracts from official reports would be of great value to show their importance :—

Captain Hastings, of H.M.S. "Howe," after six months' use of a set of revolution telegraphs. 81 indications, writes:—"I have much pleasure in informing you that they have answered admirably, and have been invaluable to me as a means of communication with the engine room." After 12 months he reported, under date September 1st, 1892 :—"I can only say that they have worked without a hitch during the whole period, and have answered the purpose for which they were fitted in a most satisfactory manner."

Captain Wm. des V. Hamilton, of H.M.S. "Blake," after nine months' use of steering telegraphs, writes, under date 6th November, 1892 :—"I am glad to be able to give you a favourable report of the working of the Willis electrical steering telegraph on board H.M.S. 'Blake.'"

After six months' use of a double set of reply revolution telegraphs, having 101 indications, Captain Hamill, of H.M.S. "Royal Sovereign," writes, under dates September 1st and December 8th, 1892:—"The telegraphs have given the greatest satisfaction. They are quite the best and certainly the only really satisfactory telegraphs I have seen, and with our other imperfect means of communication with the engine room I should be sorry to be without them. . . . . I consider them quite indispensable."

With reference to electric search lights, it might be interesting and novel to some present to hear what happened during the late wars around the coast of Egypt. To test the power of the beam, the British Consul at Port Said one night sat in the garden of his hotel and read the *Times* with the greatest of ease by the light of a projector, whose beam had been thrown a distance of 4½ miles from one of the battleships The night was fairly dark and the atmosphere quite clear. One other remarkable incident occurred during this war. Some of the ships had instructions to follow the movements of the enemy by the aid of the search light, which in every case was more than two miles from the shore. However, in spite of this great distance, it was found that millions of winged insects were attracted by this beam of light, and travelled along the beam until they struck the glass in front of the projector, and fell into the well around the search light, where they accumulated into a seething mass two feet deep, and had to be cleared out by the free use of a hose pipe. These insects were such a pest that it became difficult to find a man who would stand by the projector to keep it working, owing to the attacks made upon him.

The question of worm gearing, raised by Mr. Stirzaker, had been fully dealt with by Mr. Mountain, and it only remained for him to add that on the "Capitan Pratt," of the Chilian navy, and other battleships built in France, the most reliable and practicable means of reducing the speed of motors for use in training and elevating guns, or for other work of this nature, was found in worm gearing. Other methods of gearing were tried before worm gearing was adopted, and all proved a failure. Worm gearing was not only noiseless, but it took up an exceedingly small space, also the losses by friction had been most unaccountably reduced by correct machining of the teeth, keeping the diameters large, and particularly by running them in a bath of thick oil. The electric motor was now freely used in foreign navies, and in some liners wherever high speed was admissible.

The question of water-tightness of motors raised by Mr. Gearing had been most successfully dealt with. The whole of the machine, when this feature was essential, could be cased in, and glands used where the shafting and wires came out to be connected to their work. Many hundred motors on this principle were at present running in mines where there was an abundance of water and coal-dust, and no difficulty was experienced in keeping them in perfect working order.

With reference to the interesting electrical phenomenon observed by Mr. Sandison around the joint of a leaking steam pipe, the speaker (Mr. Sandison) was correct in assuming that the arrangement was similar, and therefore gave the same results as Lord Armstrong's hydro-electric machine. In the Armstrong hydro-electric machine the particles of condensed water in the steam were forced through crooked passages in specially constructed nozzles where friction was set up, thus effecting a generation of electricity, and where properly arranged a large supply of sparks could be obtained. In the case of the leaky steam pipe, the copper gauze making the joint was by packing or some other means insulated from the rest of the piping, and as the steam wound its way through the gauze, friction was set up and electricity was given off by the points of the gauze. Had the steam been tested by placing the hand, under certain conditions, near it, a sharp shock would in all probability have been felt, owing to the steam being charged with electricity. Steam being charged in this way had sometimes been made to do work. For example, if they wished to light the gas near to a boiler, which was in operation, partially open one of the numerous small cocks usually found on the boiler and put one hand near to the escaping steam and the other over the gas-burner, from which gas was coming out,

but not lighted, it would be found that a spark would pass from the hand to the burner, and by this means ignite the gas. To obtain this result the passage of the cock must be fairly well corroded up, and the person doing it must be standing on dry ground or be insulated, also the steam must be full of particles of condensed water.

In conclusion, he might say electricity as applied to different purposes for use on board ship was making rapid strides, and electrical appliances were gradually but surely superseding many of the old mechanical methods of working. In some navies a staff of electricians had been established, responsible for the good working of all the electrical gear on board the ship, and who have at hand all the necessary instruments and appliances for testing insulation of cables and circuits, condition of batteries, and so forth. There could be no doubt that with proper and responsible supervision electrical gear could be used on board ship for a variety of purposes, and with a speed and accuracy far beyond that of any mechanical contrivance. No doubt there were great prejudices against the introduction of anything electrical to be overcome, and it was very usual to hear that the only appliances suitable for use on board ship must be mechanical; those holding this view were only too ready to point to a single failure on the part of an electrical appliance or instrument, forgetful of the fact that mechanical telegraphs and such appliances, and even the engines themselves, occasionally failed and gave trouble. Time, however, and a better knowledge of the subject would show that electricity would play an important part in the working of all ships, and that the results obtained by its means would be relied upon with absolute confidence.

The PRESIDENT said he had very great pleasure in moving that the best thanks of the Institution be given to Mr. Newitt for the instructive paper he had read. He was sure it would be a very interesting addition to the records of the Institution.

The vote was accorded by acclamation.

DISCUSSION ON MR. S. O. KENDALL'S PAPER ON "STRAINS OF TANK STEAMERS."

Mr. E. W. De Rusett said he was very sorry indeed that the present attendance was so small to discuss this very valuable paper. He had had much pleasure in reading it, and he was struck with this, that the paper contained not only reference to the patentee's special design of tank steamer, but also gave a lot of valuable data with regard to tank ships generally. He was glad to see such a paper, especially at the present time, for when so much was heard of troubles here and troubles there, it was well to have them summed up and to have their minds directed to the points of failure and to things to be avoided in the future, as well as to such features in designs as have proved efficacious. With regard to the bulkhead liners, the writer says they should be increased in breadth and have two rows of riveting, with the object of strengthening the shell in that part. The firm whom he (Mr. De Rusett) represented were using a diamond-shaped bulkhead liner for this purpose, and they found it very palpably increased the strength; indeed, by the adoption of this form of liner they had increased the strength of the shell at this part by about 5 per cent. He had been very much interested in Mr. Kendall's tanker, and he thought it a very clever design, especially with regard to the way in which the whole framing could go on right away, and also with regard to the importance attached to continuing the unbroken strength of the various stringers; but he could not quite agree with him as to the smallness of the surface of the oil exposed to the action of the sun. The drawings before them showed the water-line fixed, but considering that at sea the vessel did not stand still but rolled from side to side, he thought in practice there would be a very large surface or film of oil exposed to the sun, and this appeared to him to be the grave defect in the design, otherwise he thought it was very good, so far as he was at present able to judge. The author deserved a meed of praise especially for the way he had investigated the strains. It must have taken an immense amount of time to have prepared such a paper, and he had done it all so modestly, for he had not devoted half a page to his own boat, all the rest being given to the science and practice of the question. He deserved their thanks most heartily.

Mr. G. STANBURY (of Lloyd's Register, London), having obtained the permission of the President to speak on the paper, said he thanked him for the opportunity to make a few remarks upon this very interesting, and, indeed, valuable paper. There was much the writer said that he could endorse from the results of his experience in connection with the construction, repairing, and the survey of oil ships that had done their work at sea for years. Of course, there were points upon which they were bound to have differences of opinion, and upon some of these he should like, if they would allow him, to make a few remarks. First, Mr. Kendall dealt with the question of safety, he thought, in a very logical and careful way. It was a point, probably, that did not receive the careful consideration on the part of the owners and officers who had charge of these ships that it ought. He himself had heard of a case a few days ago in which a vessel that had brought a cargo of crude oil in barrels from the American side, had, after she was discharged, several inches of crude oil in the stokehold limbers. Of course, it was not necessary to point out the extreme danger everybody connected with the survey of that ship was in at the time, and such a point as that, he thought, could not be too strongly emphasised, and those connected with oil ships should have their special attention drawn to the danger they were running with crude oil cargoes, which, as the writer pointed out, were the most dangerous they had to deal with. Coming to "oil-tightness," the next point the paper took up, the writer was strong in his advocacy of the continuity of the keelsons and stringers through the bulkheads. He was aware this had received support from able thinkers in the construction of oil ships, but, as far as he (Mr. Stanbury) could grasp the problem, he saw no reason for urging this continuity of keelsons and stringers. It was practically impossible to make perfectly oil-tight work with continuous keelsons and stringers without the use of the white lead injectors. There could only be one opinion expressed in the practice of using lead injectors in tank ships—it should not be done in any case. He thought all difficulties could be got over by using care in the fitting and riveting without the use of the white lead injector. Tests put upon oil ships' tanks by the water pressure would be satisfactory where injection had been used, no doubt, but, after a time, the action of the oil upon it resulted in the removal of the injected material, and they then got leaky bulkheads. As the writer pointed out, however, in his paper, directly they got into difficulties through leaks from these bulkheads they introduced very serious elements of danger to the construction of the ship, because, the tanks being only partially filled, the freedom of

motion that resulted proved in many instances most damaging to the structure. The next point was as to the use of plug-head or pan-headed rivets, as to which there were also great differences of opinion. As far as he had been able to judge, they had been able to make good work with both in oil ships. With plug-headed rivets it depended to a great extent on whether the plating inside was properly countersunk, if so, then satisfactory work would be obtained. In reference to the caulking of stiffeners, surely this was a very unusual practice. He believed one or more builders might have adopted it, but it was very unusual, and he really did not see the necessity for it. Caulking of bulkheads on both sides was very desirable and very good practice. The writer spoke of a bulkhead 23 feet by 29 feet, and under a pressure of 45 feet head of water it had a deflection of a quarter of an inch only. That was a very good result under such great pressure, and if Mr. Kendall would tell them the name of that ship they would doubtless find that Lloyd's had had something to do with the discussion of the plans. They did not want to take too much credit, but they felt there were times when they could not let themselves be placed entirely in the background. They now came to the strength. In dealing with this part of the subject (also in a very careful way) Mr. Kendall went a little out of his way to state that Lloyd's —of which society he (Mr. Stanbury) was one of the surveyors—followed the lead of another classification society. It was not his place, and it certainly was not his purpose now, to say anything to the disparagement of any other classification society; but he did think it was a pity Mr. Kendall should, in this valuable paper, have gone out of his way to attack Lloyd's. What are the facts? They would find, in a paper read by Mr. Martell, chief surveyor of Lloyd's Register, at the Liverpool meeting of the Institution of Naval Architects, in July, 1886, one of the most valuable contributions to the literature of the subject which had yet been published. It was open to anyone to consult. They would find that the chief surveyor of Lloyd's referred to the practice, then pretty nearly general, of carrying petroleum in barrels or in tin cases, as a very uneconomical way of performing the work, and that the carriage of the oil in bulk was decidedly the best. Indeed, it was brought out to such an extent in that paper that he thought he might say it gave a very considerable impetus to the oil-carrying trade. In 1886 there were probably only one or two English-owned vessels carrying oil in bulk across the Atlantic. Now, he supposed, they could be reckoned by the hundred. It was a pity, he thought, considering the impetus given by Lloyd's Register in this way to the trade, that they should be told they were only

occupying a very subordinate position in the business. Of course, they were prepared to disprove that if called upon to do so. He would have gone on, if time had permitted, to point out the many improvements, which, of course, experience had taught them, that Lloyd's Register had adopted. He had got some eight numbered, which would not take him long to read :—(1) The butts of the shell plating had been either lapped or double-strapped. (2) Closer spacing of the rivets in lands and butts insisted upon in all ships built to the classification of Lloyd's Register. (3) Form of rivets was always a subject which required the consideration and approval of the committee before the work was commenced. (4) Bulkheads and deck-plating had all to be double-riveted at the edges and butts. (5) Mid-line bulkhead considerably strengthened and made oil-tight. (6) Larger brackets to stringers and keelsons, with stiffening angles on the inner edges and double-riveted connections to stringers and bulkheads. He had no hesitation in saying that very early steps were taken to increase the brackets in that way from the results of their own experience in the matter. (7) Double-angle connection of stringers to shell for three-frame space on each side of the bulkheads was another matter Lloyd's insisted on. (8) Coffer dams to extend to the upper deck. These were some of the points insisted on by Lloyd's to render a vessel fit for classification in the society. He would like to say two or three words more on Mr. Kendall's plan. This had, of course, something to recommend it, but there was one point he was not quite at one with him upon. He said the leakage 'tween-decks of the oil steamers was due to the racking of the sides of the vessel. His (Mr. Stanbury's) opinion was, and he thought he had good grounds for it, that it was not due to the racking of the sides at all, but was due to the panting of the deck. This had been established beyond a doubt, from the fact that the riveting of the quarter stanchions, top and bottom, were frequently found torn or loose. The panting of the deck resulted from the oil getting slightly below the level of the deck, in consequence of those alternating pressures which start the caulking, and hence the leakage. With regard to the surface exposed, there was no doubt that in the swaying of the vessel the heating would be slightly increased from that cause, especially in the tropics. In regard to stability, Mr. Kendall's remarks were all very good, he had no hesitation in saying, very good indeed ; but he would like to ask him if he had read a paper by Prof. Jenkins, given in Glasgow in 1888, as to the effect on the stability from the free motion of oil or water in these tanks, and the effect on the metacentric height due to that motion ? It was a valuable contribution to the matter of stability. They next came

to the stresses, and here Mr. Kendall had opened up what they might call a new and valuable field of information for them. He had looked at them; of course it was impossible to check them, but the amount of labour in these calculations was very great. He knew what it was to calculate the strength of a ship, he had done it before, and in this case, Mr. Kendall had certainly shown himself in a very creditable light to take upon himself so much labour. Of course, his computations of the stresses were to be taken more in the sense of comparative than actual results. He had no doubt Mr. Kendall knew that as well as the rest of them. The formula he had used in that connection could not be taken in an accurate sense or in a theoretical sense to apply correctly to a hollow girder with riveted joints, such as a ship is, and, perhaps, he might have something to say on that subject at some future time. Then, with reference to the circular published by Lloyd's Register Committee, in November, 1891, with regard to carrying of water ballast in successive rather than in alternate tanks, of course, the object was to prevent local stresses, experience showing that this was required while the general strength was not in question. The paper was one upon which he might say a very great deal if time permitted; but he would conclude by saying that he entirely agreed with Mr. Kendall's remarks about officers in command of oil ships running up water ballast at sea, often in very heavy weather. He himself had seen a middle line bulkhead completely carried away simply from the fact that the officer had thought it right to run up tanks whenever he found the ship a little tender. It was a practice they could not too much condemn, and to call the attention of owners to it was the only way to prevent it. He thanked them for their kind attention.

Mr. W. Hök said he thought Mr. Kendall deserved their best congratulations on the ability he had shown in writing this paper. It was read at a very opportune moment, and he thought the more papers on oil steamers they had just now the better for this industry, because there were a great many points in connection with these steamers that were not yet generally understood. There was little to criticise in the paper, and he would therefore, with their permission, confine himself more to his own views on oil steamers, rather than occupy himself with a direct criticism of the paper. First, with regard to safety. He thought one of the most important points in connection with safety was that the coffer-dams must be absolutely oil-tight, and he thought that no pains should be too great in securing oil-tight and exceptionally strong bulkheads at the ends of the oil spaces. He was against making coffer-dams

tight, if he might say so, by water; and on the face of it, it seemed rather a wasteful method of preventing leakage by adding some 200 to 300 tons of water to the weight of the ship, and he had no hesitation in saying that the owners would not submit to it. Surely ingenuity might find some superior method of securing the end in view. He advocated the use of the double bulkhead, because it lent itself admirably to a construction of such strength and rigidity that no ordinary pressures of oil could ever make it yield if properly constructed. What they needed to guard against was that oil or vapour did not get into spaces where it was not expected to be, such as cargo holds, bunkers, tanks, etc. The oil itself was harmless enough, and generally he thought that the dangers with oil ships were grossly exaggerated. On the question of strength, he was glad to see that comparative longitudinal stresses were small in oil ships, and therefore he would suggest that they drop them for the present and instead commence looking after transverse stresses. The great weakness of oil ships was transversely, and that was what caused all the trouble. He did not know if it was generally recognised that the transverse stresses caused by a ship carrying liquid cargo were much greater than in one carrying solid cargo, especially when the ship was rolling in a sea-way. He therefore hailed with the utmost satisfaction the departure made at Barrow of lowering the main-deck. That this departure weakened the ship longitudinally mattered not as there they were strong enough. With regard to Mr. Kendall's own design, he could not agree with him that it was stronger transversely although the frames were run up, because that could not prevent the racking of the main structure from the main-deck to the keel. Another thing against it was that as there was no room for any large sized hatches on deck it left the tanks very dark when empty, which increased the difficulty and danger of cleaning them out. A friend of his also suggested that the piping arrangement would be more complicated and expensive if ships were built to this plan. With regard to fitting oil ships with shade-decks, he thought it was a huge mistake and added unnecessary expense. They were fitted for the purpose of keeping down the temperature of oil, but he believed it was a fact, and a fact which was easily explained, that it really had the opposite effect. And why should there be any need for keeping down the temperature of oil? He could not see there would be any risk of keeping the oil at a very high temperature in the tanks. It could neither burn nor explode without air being introduced, so where was the danger of excessive heat in the Red Sea, Suez Canal, etc.? There was the

debatable question, which was the best position of the engine and boiler space to be considered. For his own part he did not see the least risk in having it amidships, and it most decidedly improved the look of the ship, improved the trim, etc. The difficulty of entering the tunnel could be best solved, perhaps, by having some kind of arrangement with double, self-closing doors in the coffer-dam abaft the engine space, something on the same principle as the entrance to closed stokeholds. He thought that the oil should always be carried to the upper-deck. This matter was one of considerable importance, and of more importance than it appeared to be at first sight. The present oil ships, with a few exceptions, carried oil to the second deck only, and the result was that their transverse stability was excessive, causing heavy rolling, heavy racking, and transverse weakness. He submitted that the present type of oil ship would ultimately rack to pieces if made ever so strong, and for no other reason than excessive transverse stability through her dimensions not being properly chosen, and through oil being carried to the main-deck only. If oil was carried to the upper-deck racking in the trunks would be obviated, and likewise the escape of oil and vapours in the 'tween-decks. If oil was carried to the upper-deck, leakage, if any, would take place through the outside plating, and vapours would escape into the open air and become harmless. He now came to his final point. He had proposed that shade-decks should be done away with; that the engine and boiler space might be as well placed amid-ships; and that it was of the utmost importance that the oil be carried to the upper-deck; and until that was done they had not hit upon the right type of oil ship. His last suggestion was that the longitudinal centre bulkhead be abolished. How this bulkhead originated he did not know, probably through some insufficient knowledge of the stability of ships. The longitudinal bulkhead was not necessary for preserving ships' stability, as this could be obtained by simpler and cheaper means. It was not necessary for giving the requisite strength to the transverse bulkheads or the tank tops and bottoms. It caused more listing than if it were not there, through the impossibility of keeping the same level in contiguous transverse compartments in emptying and filling. It involved a double line of piping which could be done away with. It involved the extravagant use of material which either need not be used at all or could be better spent in increasing the transverse strength, especially beam connections. And what would be the result of a collision? If the longitudinal bulkhead was done away with the transverse bulkheads would perhaps have to be somewhat more closely spaced, and the stability

could be easily provided for, and only one line of piping would be required. In conclusion, oil steamers had given rise to so many novel and excellent departures that he looked upon them as possibly saving the profession from getting into an old stereotyped groove of building ships, from which it would have been difficult to get out. He begged to thank them for their attention, and Mr. Kendall for his excellent paper.

Mr. D. R. MacDonald said there were a few points he should like to call attention to, and, first of all, he noticed that in mentioning the principal requirements of an oil tank steamer the question of "trim" had been omitted. He thought it an oversight on the part of the writer, as Mr. Kendall knew very well there were no stevedores on oil steamers so far as cargo was concerned, and trim, therefore, lay almost entirely in the hands of the designer. On page 333 attention was drawn to the expansion trunks, which allow for increase in the bulk of oil as the steamer passes, say, from America to England. Of course, it was a very easy matter for naval architects to put these trunks in the ship and allow for 2 or 3 per cent. expansion; but, unfortunately, some captains, acting on their own authority, or on that of the owners, often filled these trunks to within a few inches of the deck, and the result was that an enormous pressure was brought on the sides of the oil compartments. Mention was made of the Suez Canal Company's regulations, and credit given to that company for the effect which these had had in improving the then existing type of oil steamer. He did not know that this credit was altogether due to the company, because before these regulations were issued there were forward coffer-dams in some steamers, and, indeed, Lloyd's insisted upon their being fitted. The writer's remark about the centre bulkhead was rather misleading. All the Suez Canal Company did was to limit the size of the oil compartments, and, of course, the cheapest way to do that was to make the centre bulkhead oil-tight. As to whether a shipowner was likely to lose 200 tons deadweight for additional security by filling these coffer-dams with water, he quite agreed with the writer in thinking it was doubtful, as he knew of a steamer that crossed the Atlantic with her forward coffer-dam actually full of oil. With regard to the difficulty of oil-tightness, in connection with the continuity of stringers, Mr. Stanbury had spoken on that point, and evidently favoured the cutting of the stringers at the bulkheads. So far as he (Mr. MacDonald) had had experience, the weakness always began at the inner edge of the bracket, and that being so, he thought that the continuous stringer should be

sought after. There would be no difficulty in getting the bulkheads tight, for, as a matter of fact, a large firm of builders on the Tyne had lately carried these stringers through the bulkheads with great success in every respect. There was no doubt the use of the white lead injector simplified things immensely, but he thought it possible to do most of the work without it. Of course, where a plate landing crossed a bulkhead frame it was impossible to do without either a stopper or an injection of some sort. Then Mr. Kendall said that it was faulty rivets which gave more trouble than anything else. He did not agree with him in that respect, nor yet with his insinuation that many rivets passed through unfair holes, and that in many cases plates had to be screwed into place with considerable force before being riveted. His opinion was that the weakness in the earlier steamers was almost entirely due to the want of riveting in the connections, and not to bad workmanship. He thought the workmanship usually met with in oil steamers was of the very best, and could not be excelled. He could not agree with Mr. Kendall in saying that Lloyd's did not insist upon the bracketing shown by Fig. 1. As far as his experience went, Lloyd's insisted very much upon it. With regard to the kind of rivets to be used, he was glad to hear Mr. Stanbury say that that was an open question, and was decided by Lloyd's as each ship was submitted for classification. He was of opinion that Lloyd's would only accept pan-headed rivets, and, in some cases, he knew they had insisted upon their use. It seemed to him that Lloyd's had blamed the plug-headed rivet for something it was not responsible for. The early steamers developed weaknesses, and consequently the plug-headed rivet was blamed for it. It was not their use, however, but the scarcity of their numbers that was to blame, and all who had experience in water-tight work would bear him out in saying that provided the hole which takes the plug-head is countersunk, this rivet gives the best and most satisfactory result. Mr. Kendall said: "A very common defect in the stability of tank steamers is that they have too great a metacentric height when in the loaded condition, and consequently great strains have been brought upon the hull by violent rolling, aggravating the racking tendency already mentioned. In the writer's opinion from 1 foot to 18 inches is ample metacentric height in the loaded condition, while there are many tank steamers running now with 2 feet 6 inches to 3 feet G.M., and in some cases these figures are even exceeded." This might be true, probably was to a great extent, but the writer evidently overlooked the fact that the metacentric height was at its minimum in the ballast condition, viz., with 800 to 1,000 tons of coal and three or four compart-

ments full of water. Allowing, therefore, 1 foot to 18 inches G.M. in this condition, with the present type of steamer, it followed that 2 feet to 3 feet G.M. in the loaded condition was a necessary evil. He (Mr. MacDonald) would suggest that bilge keels be fitted to these steamers, as this could easily be done without affecting the oil-tightness. He fully endorsed Mr. Kendall's remarks about the running up of tanks upon a sea-way. He knew of cases where captains had done so to an alarming extent—altering every gallon of water in the ship in the heaviest of weather. The concluding portion of Mr. Kendall's paper gave the results of some most elaborate calculations with regard to bending moments and longitudinal stresses on a shade-deck oil steamer. These could hardly be criticised or checked, but he had no doubt they were correct, and they certainly were very important from a comparative point of view. He was sure the Institution would feel deeply indebted to Mr. Kendall for laying such valuable information before them.

The PRESIDENT said it might be interesting for them to know in this discussion on the advantages of various types of oil steamers that a wooden ship was the first vessel to carry oil across the Atlantic in bulk. The late Captain F. Lachère accomplished this in 1868, the vessel being the "Charles," belonging to himself and his father. They had wells put into the ship, and brought them full of oil from America to Antwerp. Unfortunately the vessel while in charge of a pilot got on shore off Flushing, and Captain Lachère went on to Antwerp, leaving the chief officer in charge, placing a tug at his disposal, with positive instructions that no fires were to be lighted. The chief officer, however, allowed the galley fire to be put on. The vessel from it caught fire and was burnt. Captain Lachère afterwards went to Havre and fitted up three wooden ships to be engaged in carrying oil in bulk. They reached America, but all afterwards came to grief. The captain had told him that in crossing the Atlantic with the oil he had a chair placed on deck, and never quitted his post during the voyage. The danger, either in wooden or iron sailing ships, was in being taken aback with all sail set. This risk from our knowledge of to-day would be very much minimised, and sailing shipowners, he thought, had been very much behind in the competition to allow the steamship to take all the bulk-oil carrying trade. It might have been carried much cheaper in sailing vessels, and there was less risk of explosion or fire. The oil was a dangerous fluid, as he knew, for they had had a fire at his works through it, and he had been astonished at the way it developed itself. He threw out the idea

in regard to sailing ships, and if Mr. Stanbury would ask Mr. Martell, who knew Captain Lachère, he could tell him a great deal about his exploits.

Mr. STANBURY—Mr. Martell refers to it in the Liverpool paper I have mentioned.

The PRESIDENT said he had always been an advocate of sailing ships carrying oil in bulk, and the only difficulty was in handling the ship under sail, which was entirely due to the question of stability. If the ship could be designed to maintain the same balance as with an ordinary cargo there would be no difficulty.

Prof. WEIGHTON wished just to say a few words, and in the first place he should like to express his personal obligation to the writer of this paper. He had read it carefully, and was impressed with the great deal of trouble he had been at. He thought the Institution should certainly express their thanks to the writer. On page 334 the writer referred to the weakness shown in many of the tank steamers, and said there was "a tendency to pant in the side stringers in way of the oil compartments—a tendency much in excess of that observed in ordinary cargo steamers. In the writer's opinion this is the result of want of uniformity in the rigidity of the structure; the transverse bulkheads, which might at first sight be supposed to be a source of strength in this respect, are in reality a source of weakness, as they deprive the vessel of all elasticity, and instead of an easy imperceptible spring, extending over a large area, we have severe local vibration, resulting in slack rivets and strained connections; so great is the effect of this panting, coupled with general straining, that there are several tank steamers which have had to be almost entirely re-riveted in the oil holds. The original idea was that the increased number of transverse bulkheads would enable builders to dispense with web-frames or hold beams, but experience has shown that not only are web-frames as necessary but that a greater number should be fitted than if there were the usual number of bulkheads." He (Prof. Weighton) took it the writer meant that if they took out some of the bulkheads, necessarily in oil ships, they could take out some of the web-frames. He rather failed to understand the reasoning there. He would suggest that instead of the explanation of the tendency to pant being found in a want of uniformity in rigidity, it was largely found in the nature of the cargo; that was to say, compared with ordinary cargo. If they considered the nature of the cargo, its mobile

character, and its motions transversely to the ship, such as rolling or otherwise, the stresses will be seen to come upon the sides of the ship. With ordinary cargo the stress was largely taken on the bottom, which was made strong in comparison with the sides, against which there was no exceptional stress, unless the cargo was moving relatively to the ship. With fluid cargo the inertia due to rolling had to be overcome chiefly by the ship's sides. The diagrams, giving three or four sections illustrating the historical development of this type of steamer, upheld the view he was expressing, that it was the nature of the cargo that was to blame for this tendency to pant in the sides. This fully explained the need for the strengthening of the ship's sides, but as to the dispensing with some of the bulkheads, enabling them also to dispense with some of the web-frames or hold beams, this statement remained unexplained. He thought Mr. Hök said that the longitudinal strength of these ships was so satisfactory that it might be altogether neglected in calculation. It seemed from the author's calculations they had got to 6·84 tons per square inch compression and a little over 7½ tons tension, and this without taking account of the dynamical effects. As the factor of safety was thus something like 4, it did seem that the longitudinal strength still demanded attention and could not safely be left out of consideration.

Mr. STANBURY wished to say, in regard to what Prof. Weighton had said with regard to the movement of water or oil in tanks, that if he would bring his mind to bear upon the fact that the oil or water pressure came immediately on the plating, whereas the weight of solid cargo was brought upon the reverse frames or floors, as the case might be, he would see that with liquid cargo they had the stresses transmitted from the plating by the agency of the rivet heads to the framing; whereas, with the ordinary cargo they had the pressure carried directly by the girders themselves. The outside plating took the strains due to the liquid cargo direct.

Prof. WEIGHTON supposed the panting referred not only to the frames but to the whole structure of the ship.

Mr. STANBURY—Yes; but he would see that the shell rivets had been moving, which were indications of panting of the sides below the tank tops.

Mr. H. MACOLL could not help thinking, after hearing the opinions and experiences so well described by the previous speakers, how much

they owed to those few daring and leading minds in their nation who, after thinking out the matter of carrying oil in bulk, proceeded to put their ideas into practice without waiting until the whole question had been thrashed out in a thoroughly scientific manner. Well, those gentlemen who, had they waited until the bulk oil had been demonstrated theoretically safe and practicable, would have at this period likely been stranded amongst the different opinions given. Well, then, their leading friends with the means at hand, and what experience they could gather, and seeing their way amongst considerable difficulties and dangers, braved the risks and boldly ventured into the actual carrying out of the problem, and in the results they had now the privilege of hearing the subject deliberated on in a scientific manner, and also in the light of very considerable experience. And he wished to say they ought to accord their very heartiest thanks to the gentlemen who had opened up such a large and important industry as was comprehended in the designing, constructing, and working the bulk-oil carrying vessels. He might be mistaken, but could not help saying that he joined in an opinion very generally entertained, that their esteemed friends in Cornhill, notwithstanding the remarks of their very able representative to-night on the subject, had been a considerable distance on the other side of enthusiasm in entertaining and forwarding this industry in the early stages of its history. Even for a considerable time after the reading in Liverpool of the paper alluded to, the bulk oil vessels were only classed in the registry as experimental. In reply to this it might be said that these vessels were only in the experimental stage. He considered all vessels were more or less liable to be so described, even a first-class Atlantic liner. In referring to the paper, which he considered dealt with the subject in a sensible, careful, and thoroughly scientific manner, and he could not see where anyone could object to it in any respect, and it was a most valuable contribution to their knowledge on the subject. The subject of rivets had been touched upon. Now, it was hardly fair to put the entire defects in the early oil vessels to the rivets, *per se*. The rivets were not so closely spaced as now, consequently, each rivet had more work to do. Then the plating was not so accurately fitted, and the three-ply joint too often used. Of course, it might be the rivets themselves had not the close, continuous attention necessary, and the work in general was not of the high standard now attained in some cases. Generally, it might be said the plating and riveting were too much of the ordinary ship quality. Touching the style of rivet, he did not care much what particular style of rivet was adopted if care was not taken to

have the holes fair and the burr removed from the edge of the holes; and to get clean sharp-edged holes it was necessary to have the punches and dies kept in first-rate condition. The usual way of fitting these into the machines off the smiths' hammers did not seem to be good enough, and to ensure good work both the punches and dies should be trued up in the lathe. With the smallest burr it was exceedingly difficult to get sound, tight work, even in ordinary ballast tank work. He had seen a very handy tool for removing the burr off the edges of the holes, and also being capable of slightly countersinking the holes when desired. This was the invention of a foreman boilermaker in the district, and, especially when large or heavy plates were used, it saved the expense of taking the plates to a countersinking machine. What had been said by Mr. De Rusett about the bulkhead liners was very true, but not very new, as some of the early P. and O. liners had the identical liner fitted, and even the butts of the sheer strakes in one or two vessels he had seen were so fitted. Generally, however, it might be said so far as the quality of the labour was concerned, and especially the riveting, it would almost seem that the higher quality of work necessary for this trade would entail more cost. And he had a strong impression that it might be found to advantage to knock down the rivets in the shell from the inside of the vessel, thus ensuring the best fitting portion of the rivet where exposed to the searching qualities of the oil. Possibly some day they would have the hydraulic riveter at work, which would remedy a very large proportion of the difficulty. Personally, he preferred the pug-headed rivet, especially in conjunction with a slight countersink. No doubt good work could also be done with the thickened neck rivet, but it should be kept in mind the rivets were rarely made in the same establishment as the punch, and if in the result the two happened to fit well it was more the result of accident than anything else; and even when a punch and die were made to fit accurately, they would not long remain so under ordinary circumstances. He believed the straining at the bulkheads was due to having them too far apart, and if they were fitted closer together or strong partial bulkheads instead of the web-frames the difficulty would be almost removed, and the scending or pitching of the oil in a fore and aft direction very much decreased. There could be little doubt that by carrying the coffer dams full of water the safety of the structure would be very much increased, and if made compulsory would affect all alike, except, perhaps, those vessels which had engines amidships; still, if the latter vessels had the coffer-dam on each side of the machinery space filled it might be suffi-

cient for all practical purposes. There appeared to be a disposition to encourage the lightening of the scantlings of these vessels in the region of the neutral axis, but judging from the appearance of some of the ordinary cargo tramps, especially where somewhat short and very wide shell plates were used, this portion of the vessel was more in need of additional strength than they possessed at present. With regard to Mr. Kendall's proposal to have the oil trunks at the ship's side, he thought Messrs. Doxford's type of turret ship would make an ideal boat for the bulk oil trade. It combined Mr. Kendall's and the ordinary style, and saved the two vertical longitudinal bulkheads in the 'tween-decks, while the shape of the vessel gave no sharp corners at the lower side of the main-deck for the oil to be compressed into when rolling heavily at sea, and the turret would form a capital expansion chamber, with the further advantage that a foot or two alteration in height of the cargo would have little influence on the stability of the vessel.

Mr. RUTHVEN wished to draw the attention of members to the fact that there was a ship building on Mr. Kendall's principle on the Tees. They would all have an opportunity of seeing it and hearing of its performance when it was built.

The PRESIDENT said there was a good deal in the riveting, but much depended upon how the plates came together from the punching machine. It was a very important point in oil ships to see that the plates came close together.

The discussion was adjourned.

On the motion of Mr. MACOLL a hearty vote of thanks was accorded to the Council of the College for the use of the lecture room, and the added interest it had afforded in the electrical experiments at the former meeting.

The meeting then dissolved.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

NINTH SESSION, 1892–93.

PROCEEDINGS.

CLOSING BUSINESS MEETING OF THE SESSION, HELD IN THE PHYSICAL LECTURE HALL OF THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-UPON-TYNE, ON TUESDAY EVENING, MAY 9TH, 1893.

ROBERT THOMPSON, ESQ., PRESIDENT, IN THE CHAIR.

THE SECRETARY read the minutes of the last General Meeting, held in Newcastle, on 18th April, 1893, which were approved by the members present, and signed by the President.

The ballot for new members having been taken, the President appointed Messrs. H. Macoll and J. Gravell to examine the voting papers, and the following gentlemen were declared elected :—

MEMBERS.

Henderson, Alex., Superintendent Engineer, c/o Messrs. Empreza, Nacional, De Nav. D'Vapor.

Noble, George, Consulting Engineer, 40, Westgate Road, Newcastle-on-Tyne.

Nodder, Joseph, Furnace Manager, Messrs. John Brown & Co., Sheffield; 503, Pitsmoor Road, Sheffield.

Riley, J. H., Boilermaker, Messrs. Riley Bros., Stockton-on-Tees.

Ross, William, Superintendent Engineer, 20, Meadow Side, Dundee.

Smith, John Law, General Manager, Messrs. West Hartlepool Steel and Iron Works, West Hartlepool.

MEMBER (LATE GRADUATE).

Young, Andrew, Ship Draughtsman, 70, Falmouth Road, Heaton, Newcastle-on-Tyne.

ALTERATION OF BYE-LAW 11.

Mr. H. MACOLL moved that in the following paragraph extracted from Bye-Law 11, the words *at least two* shall be expunged, and that the word *one* be inserted in place of them:—"It shall nominate new names in the place of the retiring Members, and the number of nominations shall be, *at least, two* in excess of the number required in each section of the Council."

Mr. GRAVELL seconded the motion.

The change was unanimously agreed to.

THE VISIT TO LEEDS.

The PRESIDENT intimated that the visit to Leeds Forge would take place on or about Tuesday, July 18th. The arrangements were now completed, and he was quite sure that the visit would be no less satisfactory than was the trip to Sheffield last summer.

The discussion on Messrs. Jordan and Marlborough's paper on "Types and Proportions of Mercantile Steamers" was closed, and Mr. JORDAN replied.

The discussion on Mr. S. O. Kendall's paper on "Strains of Tank Steamers" was resumed and closed.

Closing business.

ADJOURNED DISCUSSION ON MESSRS. JORDAN AND MARLBOROUGH'S PAPER ON "TYPES AND PROPORTIONS OF MERCANTILE STEAMERS."

There being no further discussion offered on Messrs. Jordan and Marlborough's paper on the above subject the former gentleman replied.

Mr. JORDAN said the remarks of Mr. Sivewright reminded one of the long discussion on the question of the sea-worthiness of the well-deck type of vessel. The writers had a considerable amount of respect for Mr. Sivewright's opinion on the value of the various types, and admired his vigorous advocacy of the merits of the well-deck type, yet there were a few remarks in the course of his criticism which they thought ought to be qualified to some extent. This was the case, for instance, when he accused the Government of having worried the well-deck type out of existence. It was always safe to be strictly accurate in historical references, and the table on page 276 showed that instead of the well-deck vessel not now being built, it held a higher percentage ratio to the total number of vessels than any other type, and had done so since 1880. This statement was supported by Mr. Macoll. The ratio had undoubtedly fallen during the last two years, but that was accounted for by the large number of partial awning-deck vessels built during this period, which were larger in size than the well-deck type. Last year the well-deck vessels built equalled about 25 per cent. of the total of all types for cargo purposes; certainly a prominent position for a type stated to be non-existent. The writers agreed with Mr. Sivewright that the well-deck type had proved to be very safe, not on account of the wells, but because they are single-deck ships. They claimed, however, that the requirements of general cargo trading limited the profitable employment of single-deck vessels to a moderate size, and thought that this partly accounted for the decline in the relative number of single-deck vessels constructed compared with double-deck. Mr. Hök had shown, from the table already referred to, the relative decline of vessels with a break compared with those having continuous decks, and the table might be further varied by showing the relative increase of vessels with double-decks compared with those having a single-deck:—

PERCENTAGE RATIO.

Year.	Double-decks.	Single-decks.	Total.
1875	38	62	129
1880	39·9	60·2	251
1885	30·5	69·5	154
1890	47·4	52·6	380
1891	45·4	54·6	416
1892	57·6	42·4	354

Mr. Sivewright did not claim the partial awning-deck type to be an improvement on the ordinary well-deck vessel, but considered they were built solely because a reduction in freeboard was granted, and not because they gave a large amount of 'tween-deck space. The reduction in freeboard was a strong inducement to build this type, and it was only reasonable to expect that a vessel with continuous double-decks for about two-thirds the length should have an advantage in freeboard over vessels with short erections and large wells. But the gain in deadweight, owing to the reduced freeboard, was not the only advantage the filling in of the fore well produced; the additional measurement space was considered an improvement of some account, and the 'tween-decks forward of much service. So far as the sea-worthiness of the type was concerned it might reasonably be claimed that the filling in of the well did away with a space capable of holding a large quantity of water, raised the working platform for the men, gave them drier quarters, and, by giving a larger amount of surplus buoyancy, increased the range of the vessel's stability. Mr. Sivewright was of the opinion that the more general adoption of vessels with 'tween-decks was owing to Lloyd's inducing, and in some cases compelling, owners to have their vessels built in this way, and that a single-deck ship was the most profitable investment. Apart from any action of Lloyd's in the matter the writers were of the opinion that 'tween-decks for the larger class of vessel were a necessity for general trading, using the expression in its widest sense, and it might be stated that this contention was supported by the communication of Mr. Ullstrom and a number of shipowners and superintendents the writers had consulted on the matter. It had been argued in the paper that there was a type of vessel best suited for a given trade, and an owner who intended to carry only one kind of cargo, or cargoes of a similar description, would build vessels accordingly. Whilst, however, the cargoes shipped from the United Kingdom were generally of a deadweight character, a large

amount of trading continued to be done between foreign and colonial ports; and this factor, coupled with the advantage of getting home cargoes, entail and require 'tween-deck space. Adopting Mr. Hök's remark that there must be something in the partial awning-deck ship or they would not be built, the writers might say that there must be some considerable necessity in trading for 'tween-decks, or vessels so fitted would not show the steady increase proved by the foregoing table. They agreed with Mr. Sivewright that for a single-deck vessel the semi-spar-deck type had many advantages, but thought that, as with all single-deck ships, their profitable employment would be limited to a moderate size. They also agreed in condemning deeply-laden flush-deck vessels without deck erections; all the spar and three-deck vessels named in the paper had a poop, bridge, and topgallant forecastle, as shown on Plate LVIII., and nearly all the better vessels of these types were being built with such erections. Mr. Sivewright's remarks on the question of width of beam were to the point, and were in agreement with the statements in the paper. A wide ship had a longer righting lever at her maximum stability than a relatively narrower one, which however had a longer range of stability and was therefore more sea-kindly. Increasing beam without increasing depth in proportion tended to weaken a vessel. Mr. Sivewright had surely made a slip when he stated that the fact of increasing beam simply meant an increase of capacity at the top sides, because the capacity must be increased right down to the bilge, unless the increased beam was simply taken off the tumble home, which would be a most unusual arrangement. Referring to the question of tonnage measurement, the writers contended that displacement should be the principal, but not the only factor in the calculation, and by making it the basis many of the present anomalies would be avoided. Mr. Sivewright was quite right in his remarks as to the relative cost of increasing beam and depth, the statement in the paper ought to have been qualified to some extent. As pointed out by Mr. McGlashan, an increase in depth added two to the frame numeral and other numerals in proportion, while increasing beam only added one, therefore adding depth would sooner put the numerals on to other grades and increase the cost more rapidly than by adding width; the extent of this increased cost depended on the grades affected. Providing grades were not altered and the vessel did not incur increased scantling through extreme proportions, the cost of obtaining the same extra deadweight would be about equal whether it was obtained by increasing beam or depth. More draught was obtained per foot of depth increase than per foot of beam, and it therefore required less increase of depth than beam to obtain the

deadweight required. The writers did not say, or mean, that a foot of depth would cost the same as a foot of beam, nor did they say, as Mr. McGlashan's remarks would show, that increasing beam was the cheapest way to increase capacity. The statement was that it was one of the cheapest, and this was correct, providing the above grade restrictions were allowed for. Mr. Sivewright did not agree with the statement that the cost of small three-deck vessels might be less than spar-deck; this was a fact, however, and was due to the proportionately greater moulded depth, as required by the freeboard rules, for small spar-deck vessels compared with three-deck. This was shown on Tables I. and II., pages 290 and 291, as pointed out by Mr. McGlashan, and there was the further statement of the actual experience of Mr. Mulherion that he had known a spar-deck vessel cost more than a three-deck.

Mr. McGlashan in explaining why a small spar-deck vessel would cost more than a three-deck one, of similar dimensions, stated that his remarks also explained the freeboard anomaly which the writers drew attention to in the course of the paper. The writers failed to see that any explanation had been given why spar-deck vessels should have a smaller range of freeboard than three-deck. The three-deck tables were based on a minimum surplus of reserve buoyance for all sizes, and showed a considerable range of freeboards, as shown on page 286 and Table II., and it would have been interesting to have had Mr. McGlashan's explanation of why the smaller spar-deck vessels should be required to have a proportionately larger freeboard than the three-deck. If the proportionate difference between the larger spar and three-deck types is correct, a similar proportion should apply to smaller ones. But this was not so, although the smaller ships of both types were probably stronger than the larger. The writers felt that the remarks of Mr. McGlashan, in reference to the question of coefficients, were somewhat unfair, as they did not see where they had made any reference to the question which could reasonably be construed into a confession of helplessness, or that it could be stated that the members of that Institution had declared themselves incapable of dealing with the fulness or fineness of models. So far as the writers were concerned they stated definitely that vessels were being built much too full, and that the limit should be about ·78 coefficient. The firm they had the pleasure to be connected with took the most effective means of dealing with the matter by declining to build vessels above this coefficient, and the question would soon be settled if other builders who believed that it was unwise to build vessels so abnormally full adopted a similar course. But had Mr. McGlashan not missed the obvious deduction to be drawn from the

references to the fulness of models, viz., that owing to the great increase in deadweight due to the fuller models the value of Lloyd's class must vary considerably. This was shown in the remarks of Mr. Sivewright, where he gave an instance of a vessel filled out from ·7 to ·8 and carrying 793 tons more with only a slight increase in weight which would be taken up in the filling out process, no increase in the size of scantling being required for the alteration. It could not be maintained that the strength value of the fuller vessel with this increase of capacity could be equal to the finer one. This was the whole contention; Lloyd's rules allowed builders and owners to construct vessels varying so greatly, and yet having the same classification value. The builders and owners of finer vessels were handicapped to this extent. It was satisfactory to note that both Mr. Sivewright and Mr. McGlashan condemned the excessively full models, the latter gentleman stating that some vessels were built too full, that, perhaps, the limit had been reached, and that Hartlepool builders were not the worst offenders, judging from the statements in the paper. The writers had not made a statement which could be applied to any port, but are pleased to note the disclaimer from Hartlepool. They could assure Mr. McGlashan that the only difficulty encountered in carrying out the title of the paper was to keep it within reasonable limits. One proportion and speed was fixed on as the most satisfactory basis for the purpose of making the comparisons; the results of a large number of other calculations might have been included but they were of the opinion that a considerable amount of information was being given in a form and completeness probably not previously attempted, and that the most indulgent of writers and generous of firms might reasonably make a limit beyond which it would be unfair to ask them to go. The authors of the paper appreciated Mr. Macoll's remarks on this matter. They were fully aware of the possibilities of the title, the subject of comparisons being very interesting to them, but they considered that as many comparisons had been made as were practicable within the limits of a single paper. A good deal had been made of the statement that "Lloyd's rules practically fix the weight of a vessel," and they had been told that they did to a certain extent, but did not compel the fitting of deck erections, tanks, etc. This was perfectly true, and was fully known to the writers, but if an owner wished any of these things Lloyd's fixed the scantling and therefore the cost. The statement was not made and the paper was not written to apply to any special circumstances, but was intended to apply to vessels as they were built. The same remark applied to the statement that the compulsory load-line limited the carrying powers of a vessel; that was a statement of

fact, because a vessel was built and the load-line fixed, whatever her coefficient might be, her capacity was limited to the extent of her load-line; this was not so before, because the load-line was placed to suit circumstances, and when an owner wished to stretch a point and take a little extra cargo he simply loaded his vessel deeper; this he could not do now, and the vessel's carrying power was therefore limited. So far as the capacities and bunkers (Tables I. and II., pages 290-91) were concerned the writers agreed with Mr. McGlashan that the system he suggested would give the fairest comparison of the *total* internal capacity, but this was not what an owner required; what he desired was the capacity which could be used for cargo purposes, and this was given in the paper. Different types would give different space, which could only be used for bunkers, and it was useless to include this in the cargo capacities. All the vessels were based on ·78 coefficient, because the writers considered that the fairest comparison was made by this method. They did not, however, advocate this model for the smaller vessels, and if different coefficients had been chosen they would have commenced with ·74 for the smallest of the dimensions named and advanced to ·78 for the largest. It might be interesting to mention that an owner who had vessels varying from ·74 to ·77 coefficient stated to the speaker at the last meeting that the finer vessel had proved to be the most economical in all respects.

The writers quite agreed with Mr. Loveridge in condemning the excessive increase of beam compared with depth, and this was insisted on in the paper, but they did not think that many of the large cargo vessels he referred to had this defect; the increased capacity was obtained more by extra length than by excessive beam. The capacities had been calculated with web-frames fitted; if beams were fitted instead the capacities would not be affected to any considerable extent, but the stowage of course depended on the nature of the cargo.

Mr. Hök was quite correct in his statement of the method adopted in making the comparisons; this was pointed out in the paper, and the writers believed it to be the only satisfactory way, because unless length, beam, and draught were the same for the different types the basis was an unfair one. The idea was to make the comparisons, as an owner would ask for them to be made if negotiating for a new vessel. He generally fixed a draught limit, beyond which he would not go, no matter what the type might be, and it would be useless as a question of capacity comparison if the length and beam were altered. So far as the question of cost per ton deadweight was concerned, this would not be appreciably affected if the spar and three-deck vessels were increased in dimensions to take the full

benefit of the grades, and as all the comparisons had been on a deadweight basis no class had been specially favoured. The vessels had been dealt with as they were built, that was the reason the partial awning 'tween-deck height was 6 feet 9 inches and the spar-deck 7 feet. To give the partial awning-deck vessels a greater 'tween-deck height than 6 feet 9 inches would be increasing the cost without any return; the additional space could not be used, because the vessels would trim too much by the head. This, however, did not apply to the spar-deck vessels which had 'tween-deck space right fore and aft, and the 7 feet height was fixed because it was the limit the freeboard tables allowed without a deduction being made. This increased the spar-deck tonnages and weights, but gave them an advantage of capacity over the partial awning-deck class. The writers were not aware that it affected the freeboard as stated by Mr. Hök. The writers ventured to think that if Mr. Hök would base his calculations on the depth moulded, he would find the weights as given for all the types agreed with those named in the President's tables for modern vessels, especially if the different coefficients, length of erections, and class of vessel were allowed for. A percentage of the load displacement was one of the best ways to estimate the weight of a vessel, but, as with all coefficients, considerable discrimination must be used by the estimator; varying proportions and the position on the grades would affect the percentage, and even with practically the same proportions the weights varied for the vessels named in the paper in the case of the spar-deck type 2·45 per cent., and the three-deck 1·62 per cent. The weights appeared to be confirmed by the experience of Mr. Ullstrom and Mr. Mulherion.

The difference in cost between the various types could not be taken on the weight of material or equipment as referred to by Mr. Mulherion. Although he placed himself in the position of an owner, and his remarks were very interesting from this point of view, an owner would not be in a position to make such a comparison, because builders did not furnish the weight of material. This question of cost was purely a builder's one, and arose mainly through the different disposition of material in the various types. Although the weights might be the same the cost of labour might vary very much, owing to the different placing and size of scantling. Even the value of material might be different, depending on the quantity of angles, etc., compared with plates in the structure. These facts are well understood by those having an intimate knowledge of detailed costs; and the statement that Lloyd's, by fixing the weight, and therefore the cost of a vessel, must include the labour in connection with iron and steel material.

Mr. J. Denholm Young's remarks on the relative value of coefficients were interesting, and although they dealt with extreme cases they showed that the form of the model must be considered along with a statement of coefficient when the question of speed was being discussed. Although the displacement coefficient might be the same in two vessels the form of model might vary very considerably, and affected the speed when engines were being driven at a maximum power. Some builders preferred bluff ends and a rounded bilge, others adopted the reverse form, while many vessels were built with both full ends and bilge.

The writers appreciated the friendly tone of the criticism which had been passed on the paper, and regretted that the opportunity had not been taken by more of the shipowning members of the Institution to give the result of their experience with various types, Mr. Yeoman having been the only shipowner who had spoken. Information of this character would be of considerable value to builders who were ever anxious to make such improvements as were suggested in the general working of vessels.

The PRESIDENT moved that the thanks of the meeting be given to the writers of the paper. He thought he was right in doing so, for although the information was partly from his firm, he thought it a valuable paper, and that the information given would be more appreciated when it was more carefully studied. He regretted, along with the writers, that there had not been a full discussion by shipowners, and that they had neglected the opportunity given to them by the paper. However, that did not detract from its value, although the Transactions might probably have been made more interesting if the discussion had been more complete, but those who had failed to take part in it would be the losers. He had pleasure in moving that the best thanks of the meeting be given to Messrs. Jordan and Marlborough for the paper.

The vote was accorded by acclamation.

ADJOURNED DISCUSSION ON MR. S. O. KENDALL'S PAPER ON "STRAINS OF TANK STEAMERS."

Discussion was resumed on Mr. S. O. Kendall's paper on "Strains of Tank Steamers."

Capt. T. McNabb said that as he was abroad at the time of the first discussion on the paper he would not now have intervened only that he had noticed that Mr. Stanbury, when commenting on the paper on the occasion of the first reading, took credit for Lloyd's on account of the impulse given by that Register to the promotion and development of the trade in tank steamers for carrying oil in bulk, and particularly for the effect of Mr. Martell's paper read in 1886 at Liverpool. He (Capt. McNabb) had not read that paper and could say nothing about it, but he took exception to the claim put forward on behalf of Lloyd's in this connection. He thought he might claim to have been the first man to have made a contract for the conveyance of oil in bulk next to the skin of the ship. He was aware the S.S. "Fergusons" was already chartered for the trade, but her arrangement was a series of tanks built outside the vessel and then stowed inside. His contract was made in March, 1885. He did not claim any merit for the idea. A foreign merchant came to this country at the time and submitted his proposal for a contract for this style of vessel to some merchants or shipowners who were unable to grasp the subject. He did not claim any particular merit for grasping it, but he did grasp it, anyhow, and entered into a three years' contract to supply such a steamer. From March, 1885, till August of the same year he was working out the details of the scheme, and in the latter month he went to Lloyd's in London to get the class for carrying petroleum in bulk; he took his plans and submitted them, but his proposals could not be listened to. He declined at present to mention names as there was no one present whom he met on the occasion he referred to. There was only one way that Lloyd's would accept such alteration or construction, and that was that there should be one vessel inside another. One reason for this demand was that if the vessel collided or got damaged the men could go round between the two shells to do the necessary repairs. The next objection was that if a vessel carried oil next the skin, and there was a collision, the oil would escape. His reply to that was that if the oil escaped the water would take its place and the vessel

would still float, the only difference in the circumstances being that she would take a list to the extent of the difference in weight between oil and water. Another argument—and it was the most extraordinary argument of all—was that the oil would percolate through the plates. The reply he gave was that, if that were so, the oil would lubricate the sides and make the vessel go easier. The result of Lloyd's refusal to class that vessel was that he lost a certain class of business that he should have had, being, as he was, first in the field. Another association took the matter up in a more intelligent manner than what Lloyd's had done, with the result that the latter had to follow suit and give their class to vessels for carrying oil in bulk against the main shell. The encomiums passed on Lloyd's for what they had done with respect to carrying oil in bulk appeared to him to be perfectly absurd.

Mr. J. GRAVELL said he was sure it would have been much better had some shipbuilder or shipowner taken up this question more able to put before them the merits due to Bureau Veritas in taking up the lead in the classification of oil steamers. By this he meant vessels of all classes—sailing ships or steamers—which had carried oil right out to the skin. In November, 1886, the late Mr. B. G. Nichol and himself read a paper before that Institution on the "Use and Transport of Liquid Fuel." This paper was ready some months before it was read, but owing to the session of the Institution not beginning before October its delivery was deferred to the aforementioned date. In the summer of 1886 Mr. Martell read before the meeting of the Institution of Naval Architects in Liverpool the paper referred to by Mr. Stanbury; but it was not going too far to say that the views expressed in that paper did not then coincide with those acted upon in the classification of the ships in question by Lloyd's society. Mr. Martell in his official capacity then insisted that oil steamers which were intended to carry oil in bulk should have a double skin similar in construction to the steamers "Westernland," "Vaderland," and "Sviet," which were, however, also classed with Bureau Veritas. The first ocean vessel which carried oil in bulk with single skin was built in the early part of the year 1886 by Messrs. Sir W. G. Armstrong, Mitchell & Co., and was named the S.S. "Glückauf," and this vessel was classed in Bureau Veritas only. The second was built by Messrs. Sir William Gray & Co., West Hartlepool, named the "Bakuin," surveyed by Lloyd's Registry, and entered in their register book with the proviso "that the class did not extend to petroleum fittings." There were plenty of shipbuilders and shipowners now who could bear out Mr. Kendall's

statement that Bureau Veritas took the lead in the surveying and classification of petroleum-carrying vessels. The following were the particulars of new oil vessels classed up to the end of July of last year:—With Veritas, 61; Lloyd's, 19 (these figures do not include old vessels which have been altered for the carrying of oil in bulk): If desired he should be most happy to give the names, dates of building, etc. He might state that he himself discussed the plans for the building of oil steamers of the present type with Mr. Swan and Mr. R. S. White, of the firm of Sir W. G. Armstrong, Mitchell & Co., as early as August or September, 1884, and that a small vessel was then approved, but the construction of the same was not proceeded with, as Mr. Riedemann ordered at a later date the S.S. "Glückauf" in place of the one then projected.

The PRESIDENT said it was well to get at the truth, and what had been said on the subject of the classification of oil steamers would, he thought, be beneficial to both societies. It was an interesting paper and put a lot of valuable information before the public. He could speak of the interest taken personally by Mr. Gravell in the oil tank steamers. All he knew of them had been got through him. A careful study of Mr. Kendall's paper should give owners a good deal of confidence in the building of oil steamers; and if it conduced or helped in any way to make them more perfect the Institution should have some credit for having obtained such a paper from Mr. Kendall.

Mr. ROBT. H. MUIR—Like those who have already spoken in this discussion, he would like to thank Mr. Kendall for the valuable information he had put before them relative to the construction of tank steamers. He had in that paper shown himself thoroughly conversant with the construction in all its details. He would like to ask a question upon what Mr. Kendall said in page 330, that "another rule, which should also be observed as much as possible, was to fit all connections metal to metal, and avoid the use of all felt, packing, or white lead as much as possible." He would like to have the "as much as possible" defined. They all knew how difficult it was to get caulkers to trust entirely to the caulking and good fitting without the use of felt or canvas to help it. So far as he understood water-tightness or oil-tightness of tank work it was simply a matter of educating platers up to a much higher standard of workmanship. Mr. Macoll at the last meeting referred to the necessity of having their punches and dies in thorough good order so that all rags or sharp projections round the punched holes of the plates might be avoided. If

this is not done it is necessary to clean these off by some means before a good metal to metal connection can be got. No matter how efficient the riveting may be it will never make up for bad fitting. With regard to the strength of these vessels. He was at present engaged in building a coasting vessel that had a bilge keel of bulb and tee iron an upper bilge rubber of flat iron, and a heavy wooden belting at the line of main deck, between double angles; these must add considerably to the longitudinal strength of the vessel, though in this case they are not put on for that purpose. It occurred to him, that for steamers carrying cargoes of oil in bulk, a series of such straps fitted along the outside strakes would materially assist in taking the strain off the rivet heads through the frames, and bind the stringer connections at the bulkheads. They would all agree that the relative position of the frames and plating would be better transposed in oil-carrying steamers, *i.e.*, the frames outside and the plating inside. The custom sometimes resorted to with the old "wooden walls" of undergirding the ship was a very good expedient and oftentimes efficient. But those days have gone, and modern science must invent a substitute. An objection might be raised to riveting these straps through the frames, seeing it would be three-ply, but if the holes were drilled little objection could be taken. He would be so confident of the benefit to be derived from this binding that he would suggest reducing the shell plating somewhat to compensate for the increase of weight. Whether the registering societies would comply with this request is quite another matter. The sketches in Mr. Kendall's paper relative to the progressive steps taken to strengthen the junctions of bulkheads and stringers are very interesting, for this is the weak point, and undoubtedly has given most trouble in the construction of tank steamers.

Mr. Theo. Doxford said, as one of the Past-Presidents of the Institution, he would like to add his thanks to those which had been expressed to the writer of this something more than able paper. He thought, out of the great number of very valuable papers which they had had, papers, he believed, which were equal to any which had been read before any institution in the kingdom, this paper of Mr. Kendall's would stand well to the forefront. There was only one point he should like to refer to, that was a remark by Mr. Stanbury about the longitudinal strength, in which he did not feel at all disposed to concur. He said that in giving oil-tightness the writer was strong in his advocacy of the continuity of the keelsons and stringers through the bulkheads. With that he entirely concurred. But Mr. Stanbury went on to say he was aware

that this had received support from able thinkers in the construction of ships, but he saw no reason for urging the continuity of keelsons and stringers. It was practically impossible to make oil-tightness without the white lead injectors. He (Mr. Doxford) thought that good workmanship would probably overcome the difficulty in making the work oil-tight, but he rather feared no amount of work would overcome the inherent defect of breaking the longitudinal strength of the vessel. He thought everything should be sacrificed, especially in this class of vessels, for continuity of the longitudinal strength of the ship, and to overcome any defect or difficulty in making the joints through the bulkheads tight, extra care should be taken in the workmanship.

Mr. T. Millar said he must compliment the writer upon the amount of information he had introduced into his paper, which certainly showed that he had devoted a great amount of time and care to its preparation. He was sorry to say he had not been in a position to examine the paper thoroughly, and had only been able to make a few marginal notes. He might say that the first steamer constructed to carry oil in bulk across the Atlantic was now lying ashore on Fire Island, and he did not suppose she would ever get off. The exhausting of oil-gas from the tanks in these vessels had been tried with varying success, and he thought before long they would have an effective arrangement for this purpose. The explosions which had occurred in oil steamers had, as far as he was aware, happened in vessels which carried crude oil, and he did not think there had been any explosions in steamers carrying refined oil, although there had been fires. Mr. Kendall spoke about sufficient margin being left in the oil trunks for expansion of the oil at varying temperatures. He (Mr. Millar) was afraid that so long as there was any space left in the trunks there would always be a certain amount of danger that captains, anxious to do their best for their owners, would occasionally be tempted to fill them right up, and leave very small margin for expansion. Trouble had occurred before now through filling the trunks too full, and if the owners had said nothing about the matter, other people had not been backward in giving their opinion on the subject. Regarding the statement that the oil compartments in these vessels range from 24 to 28 feet, he (Mr. Millar) knew that they ranged from 20 to 40 feet in length, although in the case of the 40 feet compartments the oil had not been carried to such a great height as in the shorter ones. The effect of the regulations issued by the Suez Canal Co. for oil vessels passing through the canal had been beneficial in some respects upon the arrangement of

these steamers. He did not know whether owners paid any more for the additional structural arrangements, but certainly they entailed a good deal more work and expense upon the builders. As to the stopping of the stringers and keelsons at the transverse bulkheads, he, in common with others, had thought it advisable to avoid piercing the bulkheads more than was absolutely necessary, and this practice until recently was carried out, the stringers and keelsons being connected to each side of the bulkhead by angle bars. There had been so much trouble with these connections that lately it was considered advisable to carry the stringers through the bulkheads and fit double angle iron collars. This modification had not yet been extended to the keelsons, but no doubt they will ultimately be dealt with in the same fashion if found advisable to do so. Mr. Kendall said he did not see any difficulty in piercing the bulkheads, and that experience had shown that it was faulty rivets which gave the trouble more than anything else. There was no difficulty in piercing the bulkheads at all, the trouble lay in getting them tight after they were pierced. The principal trouble in these vessels did not arise from faulty rivets so much as from insufficient connection. The rivets in the bars connecting the stringers to the transverse bulkheads, which gave way through the bulkhead, were few, as a rule, compared with the number started in the fore and aft flange of the bars. The spacing of rivets had been arrived at by experience. What was said about double riveted seams and bars was very true, as very little trouble arose where this practice was carried out. Single riveted bars subject to strain often caused much trouble, whereas double riveted bars generally performed their work satisfactorily. Regarding bulkhead liners which Mr. Kendall said should have two rows of rivets on each side of the frame bar, he (Mr. Millar) had never heard of liners with only a single row of rivets in each side having shown signs of weakness or fracturing in any way. With regard to fracture, he had been told the other day of a curious thing which had occurred to several oil steamers. On the shell plating, half-way between the keel and main-deck, and somewhere between the engines and boilers, one of the shell plates had broken right across. Still more curiously, this was not confined to one side of the ship, but the corresponding plate on the opposite side was damaged in the same way. It was a strange place for straining to show in such a marked manner, and so far, no one had been able to account for it satisfactorily. Any one who has had any experience with these vessels was surprised at nothing he saw on board of them, as plates break, rivets shake loose, and signs of straining are noticed in the most unlikely places, and where one

would least expect to find them. He had seen the plates of the centre bulkhead broken for 5 or 6 feet along the top of the main-deck bar, and also cracked under the spar-deck. The form of rivets used in these vessels had been, and was still, the subject of considerable discussion. The plug-headed rivet was the form which had generally been adopted, and so far as oil-tight work was concerned had done its work efficiently. He had heard it said that Lloyd's insisted upon pan-head rivets being used, but he thought this was a mistake. He had discussed the matter with Lloyd's on several occasions, and although he found they favoured the pan-headed rivet with a tapered neck, yet they were quite willing to accept the plug-head rivet, provided the head was of sufficient depth. As to the caulking of the bulkheads, he did not know what the general practice was, but the firm he was with were in the habit of caulking the bulkheads on both sides, as it was found there was less trouble in the testing of the tanks than if only one side were caulked. Then as to the testing of the tanks, great diversity of opinion existed regarding the water pressure to which the tanks should be subjected. Some vessels had been tested with a head of water 20 feet or more above the main-deck, but the general practice was 11 feet above the main-deck. It was quite possible to overdo the testing, thereby subjecting the vessel to a pressure which would do positive harm to the structure, without any corresponding advantage to the vessel. A pressure of 10 to 12 feet over the main-deck was quite sufficient for all practical purposes, and in excess of any pressure which the vessel would undergo in actual working. It must be remembered that those vessels were tested with water on the stocks, when they were only supported on the bottom, a very different condition from being afloat, when the pressure of the oil or water, with which the vessel was laden, is counterbalanced by the pressure of the water in which the vessel was immersed. Great care should be exercised in docking these vessels, and tanks filled for trimming purposes should be emptied as the water leaves the vessel, otherwise straining may result while the vessel is resting on the keel blocks only. Referring to Fig. 2, Plate LIX., Mr. Kendall says: "In a connection of this kind, weakness shows principally in the rivets marked XX." In this he is partly right, but it was when single bars only were fitted that these rivets caused trouble, and even then the rivets started were principally in the horizontal flange of the bar, and not through the shell as indicated. It was to overcome this trouble that the double bars were fitted, and so far the results have been satisfactory. Bureau Veritas are credited with having introduced the arrangement of stringer brackets shown in Fig. 2, Plate LIX.,

but with all due respect to the society, and while fully recognising all they have done and are doing for the development of the modern tanker, he did not think the arrangement was entirely due to them.

Mr. GRAVELL—It was due to Mr. Millar.

Mr. MILLAR said he did not lay any claim to the arrangement. He thought it was a pity that any comparisons should be made between Bureau Veritas and Lloyd's, as he was quite sure both societies were doing their utmost to assist the shipbuilder to turn out tankers which would be satisfactory to all concerned. He saw Mr. Kendall had made his calculations of strain for a shade-deck steamer. He (Mr. Millar) thought he was right in saying that there was only one vessel of this particular design in which the upper-deck forms the tank-deck proper, with the expansion trunks extending to the shade-deck. In the other shade-deck steamers which have been built, the main-deck forms the oil-deck. He had much pleasure in thanking Mr. Kendal heartily for his very able paper.

MR. KENDALL'S REPLY.

Mr. S. O. KENDALL, in reply, said he had to express his thanks for the very courteous and liberal manner in which this contentious subject had been treated. He was much obliged to Mr. De Rusett for his remarks on his patent tank steamer. With regard to his objection on account of the additional exposure of side when rolling in a sea-way, it must be remembered that rolling had its corresponding advantage, as every roll would dip the side under, and thus neutralize the effect of the alternating exposure. He had never heard of serious inconvenience arising from exposure, although he had known vessels with not only the side up to the weather-deck, but the whole of the deck and the trunks exposed.

In reply to Mr. Stanbury's interesting remarks, he must at the outset express his regret that he should have considered the remark he made as to Lloyd's following the lead of Bureau Veritas in matters relating to the construction of the modern tank steamer, that was of the tank steamer carrying the oil out to the skin of the ship, as an attack upon the former society. He could assure him that it was never intended as anything of the kind, but was simply what he believed to be an accurate statement of the facts of the case without prejudice either for or against either society. In order that the meeting might judge in the matter, he would briefly state the grounds on which his belief rested—grounds be it noted which, so far as he was aware,

had not been disputed. In 1885 Mr. Martell was approached by Mr. Swan, of Messrs. Armstrong, Mitchell & Co., with a view to classing an oil steamer in which it was proposed to carry the oil out to the skin of the ship, as in the case of the small steamers trading on the Caspian. Mr. Martell objected to this as a departure which could not be approved, the previous vessels for ocean trading having had a complete or partial double skin. Bureau Veritas, on the other hand, accepted this vessel as the type from which the most satisfactory tank steamer could be developed, and time has shown that this line was the correct one. In July, 1886, Mr. Martell read a paper in which he demonstrated very clearly the commercial advantages of carrying oil in bulk, but it must be remembered this had been advocated, though perhaps not so ably, for many years previously. The question was "Which is the best way to do it?" and unfortunately the paper by Mr. Martell did not enlighten them on this point, although it afforded a most excellent *résumé* of the different methods which had been adopted up to that time. In treating of the proposed departure of carrying the oil out to the skin of the ship, then being introduced in the S.S. "Glückauf" by Messrs. Armstrong, Mitchell & Co., he remarked:—"The plan for making the outside plating of the vessel form the sides of the cisterns in which the oil is to be carried, although adopted with success in the Caspian, has only now begun to be employed in vessels engaged in over-sea voyages. Great care, as has been shown, has been taken to make the vessels oil-tight, and doubtless for some time they may be found to be so, but it must be borne in mind that vessels have to encounter heavy seas and frequently come in contact with wharves, barges, and other structures, with sufficient force to start the riveting and caulking and cause leakage, so that the plan may be said to be as yet on its trial." It was no doubt in consequence of this suspicion of the merits of the single-skinned tank steamer that Lloyd's refused for some years to class these vessels except with the proviso that the class did not apply to petroleum fittings, while in the meantime Bureau Veritas were accepting and developing these vessels, and so were taking the lead in matters relating to the single-skinned tank steamer, as the figures given by Mr. Gravell showed. These were the facts as they stood recorded in the *Transactions of the Institute of Naval Architects*, Vol. 28; in the *Transactions of the Institute of Engineers and Shipbuilders in Scotland*, Vol. 32; and in their own Transactions, Vol. III, pages 41, and Vol. VI, page 42; and if he was wrong in being guided by these records, he submitted that it was the fault of Lloyd's in allowing these statements to be inserted in the above volumes unchal-

lenged. He did not think any one would consider the hesitation shown by Lloyd's in accepting the single-skinned tank steamer to be a reflection to the discredit of that society. No doubt there would be many who would think with the late Prof. Jenkins that they were justified in the course they took; but, on the other hand, he was sure no one would grudge to Bureau Veritas the credit of having come forward and accepted what had eventually proved to be the most successful type of tank steamer.

He could not agree with Mr. Stanbury that there was no reason for urging the continuity of the stringers through the bulkheads; as in spite of all the care and riveting put into these connections they still continued to give trouble, and with special attention being given to the fitting of the collars there should be no difficulty as to oil-tightness. He could assure Mr. Stanbury that the caulking of the stiffeners and connecting angles on oil-tight bulkheads was by no means uncommon, and in some cases it was absolutely necessary in order to make a satisfactory job. He was afraid Mr. Stanbury's impression of the leakage into the 'tween decks and working of top sides did not coincide with his experience. He understood that the leakage occurred to a great extent in the angles connecting the frame top brackets to the main-deck, and he failed to see how this could be produced by the panting of the deck; nor did he understand how the oil could get below the level of the deck, except through accidents, which it was to be hoped were not of frequent occurrence. In support of his contention Mr. Stanbury quoted cases where the rivets in the quarter pillars had been sheared. He would suggest that this result might have occurred in the cases to which he referred from panting of the bottom, a theory which was extremely plausible, considering the very great variations of fluid pressure. He agreed with Mr. Stanbury that the strains given in the tables must be treated as comparative rather than actual strains, as in all calculations of a similar kind; in fact they only got their ideas of the strength of vessels by comparison. He had hoped on seeing Mr. Stanbury's name in the discussion, that he would have been able to endorse or otherwise some of the figures he gave in the tables. However, perhaps the remark that he might have something to say on the subject at a future time might not be unconnected with his reticence on this point, and he was sure his communications, which would, no doubt, be of a valuable character, would be awaited with considerable interest. Mr. Stanbury asked him if he had read a paper by the late Prof. Jenkins on the "Stability of Oil Steamers." He might say that he had read it and

considered it a most valuable article. In was interesting to note that whereas he gave a theoretical demonstration of the danger of filling or emptying all the oil compartments at once, he (Mr. Kendall) gave a practical illustration of the same danger having occurred.

In reference to Mr. Hök's remarks on oil steamers, he could not do better than to refer him to the above-mentioned paper by Prof. Jenkins, wherein he would find the value of the centre bulkhead fully demonstrated and conclusively proved. Again, Mr. Hök advocated the placing of engines and boilers amidships. He was aware this had been adopted in some vessels; but the difficulty and danger of the shaft tunnel was an almost unsurmountable one.

Mr. MacDonald was in error in assuming that the omission of trim from the paper was an oversight; it was intentional and fully considered. The trim of a tank steamer, though a matter of considerable importance in the drawing office, was not considered to be within the scope of the paper, and so was omitted. Mr. MacDonald seemed to have missed the point of his remarks about leaky rivets and riveted connections; the former remark referred to leakage, when testing only, and as to the latter, all practical men would admit that iron or steel shipbuilding had not yet arrived at a state of perfection. He could quite agree with Mr. MacDonald as to the excellence of the work to be found in tank steamers, but it was far from perfect, and it was to these almost unavoidable imperfections in the punched holes of ship work that he referred to, not as a reflection on the class of work, but as elements of inaccuracy which could not be ignored, and which necessarily affected the value of a connection composed entirely of rivets, and without the frictional resistance which was so important a factor in an ordinary lap butt. With regard to Mr. MacDonald's remark that stiffeners was a necessary evil in certain tank steamers, he gave the figures 12 inches to 18 inches in a general way, and although he was fully aware that in the particular type he referred to, extreme stiffness was an evil, though he would hardly call it necessary, he failed to see how it affected his contention that 12 inches to 18 inches was ample, and he thought it would be admitted that if the above figures were exceeded it was to the detriment of the design.

In reply to Prof. Weighton's remarks as to why a wider spacing of bulkheads admitted of a corresponding wider spacing of web-frames, he could only say that in practice it was so. In a sailing vessel recently built the holds were 40 feet long and had only two webs in each hold, which was the number generally fitted in a hold 24 feet long. There was a very large field for investigation in Prof. Weighton's remarks

about the inertia of the oil. He quite agreed with Prof. Weighton that the longitudinal strains given in the tables were not so moderate that they might be ignored as an instance of the effect of compressive strains. He might mention that in a shade-deck tank steamer recently built, four of the central adjacent tanks were filled with water, and under this load in still water, the shade-deck stringer was found buckled $\frac{7}{8}$ of an inch between the beams in several spaces. He calculated the bending moment in this condition and found it to be 60,000 foot-tons sagging, while the compressive strain on the shade-deck stringer amounted to 5 tons per square inch.

With regard to Capt. McNabb's remarks about the escape of oil in the event of damage to the skin plating, he quite agreed with him that very little oil could escape, by reason of the pressure of water on the outside, and he believed that where accidents of this kind had occurred, very little oil had been lost. He would like to mention with regard to Mr. Gravell's remarks, that the S.S. "Bakuin" was not entirely a single-skinned vessel, as she was fitted with a double bottom all fore and aft, although the oil was carried out to the sides of the vessel.

He could not see that the longitudinal girders mentioned by Mr. Muir would much increase the strength of tank steamers, for, as far as he knew, the weakness was in the transverse rather than the longitudinal strength; there was a difficulty in riveting these bilge keels to the frames, and, as far as his experience went, the practice had been to omit the rivets through the frames altogether.

Mr. Millar drew attention to the fact that there have been no explosions with vessels carrying refined oil. He might mention that unless he was very much mistaken the "Petriana" carried refined oil and suffered a disaster. Mr. Millar also said that the length of petroleum holds ranged from 24 feet to 40 feet. The figures, 24 feet to 28 feet, he (Mr. Kendall) gave referred principally to steam vessels, and, as he had previously stated in his reply, 40 feet had been reached in sailing vessels. Within the last few days a case of holds, 34 feet long in a steamer, had come under his notice, but it should be mentioned that in a subsequent vessel for the same owners the holds were reduced to a more moderate length. With regard to these long holds it was certainly a danger in the case of any accident and the oil getting below the level of the deck; the motion of the oil through the vessel pitching would have a serious effect on the bulkheads. It was perhaps hardly correct to show a double cross in Fig. 2, Plate LIX, but he thought his meaning was clear enough when he said that the double bar had been entirely satisfactory. There was

no doubt much had to be explained in this class of vessel; but it was equally certain that by reading the lessons of experience aright every difficulty would be removed. He was much obliged for the kind way in which the paper had been received, and thanked the members for their attention.

The PRESIDENT moved that the best thanks of the Institution be given to Mr. Kendall for his valuable paper. He certainly could not complain of lack of discussion, which was a great compliment to the paper.

The vote was accorded by acclamation.

CLOSING BUSINESS.

Election of Officers.

The following was announced to be the result of the ballot for filling vacancies in the Council of the Institution:—

President—Mr. Robert Thompson. (Re-elected.)

Vice-Presidents—Mr. W. Kilvington, Mr. A. Laing, and Mr. J. F. Walliker.

Honorary Treasurer—Mr. G. E. Macarthy.

Council—Mr. C. D. Doxford, Mr. H. Fownes, Mr. W. Hök, Mr. E. W. De Rusett, and Mr. J. C. Stirzaker.

On the motion of Mr. Sandison, seconded by Mr. H. Macoll, Mr. R. W. Sisson was re-elected Auditor.

Vote of Thanks to the Council.

On the motion of Mr. Millar a cordial vote of thanks was accorded by acclamation to the Council for their services during the past year.

The President commented upon the usefulness of fresh blood being always brought into the Council, giving a larger interest in the conduct of the Institution. This closed the session. Their next meeting would be in connection with the visit, in July, to the Leeds Forge.

VISIT TO THE LEEDS FORGE.

In response to the kind invitation received by the Council of the Institution from Messrs. The Leeds Forge Company a visit was paid to their works, situated at Armley, near Leeds, on Tuesday, July 25th.

A special train was despatched from Newcastle-upon-Tyne at 9·33 a.m. in connection with ordinary trains from Tynemouth, South Shields, Jarrow, Sunderland, the Hartlepools, Middlesbrough, and Stockton-on-Tees for the convenience of members.

The party arrived at Harrogate at noon and were there joined by members of the Hull and District Institute of Engineers and Naval Architects. Both parties proceeded to Grove House, the residence of Mr. Samson Fox, Managing Director of Messrs. The Leeds Forge Company, where they were entertained to luncheon in a large marquee erected for the occasion.

At about 2·20 p.m. the whole party left for Leeds, arriving at Armley station (adjoining the works) shortly after 3 o'clock.

These works, a bird's-eye view of which is shown on Plate LXVII., are situated at Armley, about two miles from the centre of the city of Leeds, and cover about 20 acres. They are well provided with carrying accommodation, having on the northern side the Leeds and Liverpool Canal, by means of which a large proportion of their supplies is delivered; and on the west by the North Eastern Railway, crossing by a siding connection with the Midland Railway, communicating with all departments of the works.

The works were founded in 1873 as a private limited company, and for some years were principally engaged in the production of best Yorkshire iron for various purposes.

In 1889 the business was transferred to the existing company, with Mr. John Scott, of Greenock (for many years associated with the old company), as Chairman, and Mr. Samson Fox, the founder of the original concern, as Managing Director.

In 1877, Fox's corrugated boiler furnace was introduced and manufactured at these works, enabling the comparatively low steam pressures of that period to be considerably augmented to meet the demand inseparable from the use of triple expansion engines. Prior to 1883 all Fox's

furnaces were manufactured from best Yorkshire iron, but in that year the company, recognising the greater reliability and uniformity of Siemens's steel for that purpose, abandoned the use of iron and erected Siemens's open-hearth furnaces, with the necessary rolling plant, producing a very mild quality of steel ranging from 23 to 26 tons per square inch, which was invariably employed in the manufacture of all their boiler furnaces, until lately a higher tensile strength of material came to be allowed by the Board of Trade and Lloyd's surveys.

The number of Fox's furnaces supplied exceeds at this date 30,000, embracing diameters up to 4 feet 10 inches outside corrugations, and worked under pressures gaining up to beyond 200 lbs. per square inch. 131 vessels of Her Majesty's navy have been fitted with these furnaces.

To this department of the works has been lately added the manufacture of Morison suspension furnace, a type of construction, which, whilst retaining all the advantages of the older form of corrugation, is intended to obviate objections connected with the deposit and removal of scale accumulations. Although not approved by the official surveys for general use until towards the end of 1892 upwards of 1,000 of these furnaces have already been supplied.

Another branch of industry was inaugurated about the year 1887, when a large hydraulic press capable of exerting a pressure of 5,000 tons was laid down for the purpose of producing patent pressed steel frames, on Fox's system, for railway rolling stock; the object gained being increased strength and lightness of construction. These plates are flanged in suitable dies at one heat; and under-frames and bogies constructed under this system by the Leeds Forge Company are now in use on fourteen English railways, and have been largely employed by the Indian and colonial state railways.

The same hydraulic press is also used for the flanging of the front and back end plates and combustion chamber plates of marine boilers, more particularly for Government contracts.

There are now also produced in this department pressed steel axle-boxes (Fox's patent system) made from a single plate, thus saving considerable weight, and preventing the breakages so common in cast boxes.

The visitors were conducted to the inspection of the various processes by Mr. Samson Fox, assisted by Mr. Bernal Bagshawe and the officials of the company.

Having visited the steel furnaces, where ingots were being cast, and having witnessed the hammering down of ingots into slabs, a plate for one of 42 corrugated furnaces, on order for the Russian Government, was

rolled. Afterwards, the bending of a furnace plate into cylindrical form preparatory to welding was effected, and great interest was shown in the subsequent operation of welding such tubes by means of the special appliances in use at these works. The mode of operation was as follows:—Each cylindrical tube having been bent up with a lap of about 2 inches was secured at the ends, and placed upon a carrier situated so that the joint was brought at intervals under the powerful heat of a mixture of ignited water-gas and air; and when at welding heat, the furnace travelled forward to the anvil placed immediately behind the jets, and was completely welded by the rapid blows of a steam hammer. The superiority of these welds may be gathered from the fact that they have been found to possess over 90 per cent. of the strength of the solid plate.

The party next visited the corrugating mill, a machine made from Mr. Samson Fox's designs, and driven by a pair of compound engines indicating 1,000 horse power. A welded plain tube, being one of 24 corrugated furnaces intended for H.M.S. "Talbot," having been heated to a uniform bright cherry-red was placed in the rolls and corrugated in the following manner:—The principal roll was slidden inside the welded cylinder, auxiliary rolls centred the flue, and the two main rolls being brought close together by hydraulic power impressed the corrugations into the plate, and by starting the engines the flue was corrugated at one revolution, though the rolls were allowed to revolve until the flue was sufficiently cool to allow of removal without distortion, the auxiliary rolls being kept just touching what was now a revolving corrugated flue, and so practically producing a true circle.

The flanging shops were next visited, where a number of corrugated furnaces and suspension furnaces were seen in the various stages of development, so far as concerned the wing-flanges; after which the final processes of annealing, machining the ends, and final critical inspection before delivery, were carried out in every instance.

The visitors had an opportunity afforded to them of inspecting the water-gas plant, which is used in welding and other metallurgical operations at the Leeds Forge. The process consists of passing steam through a mass of incandescent fuel obtained by means of a powerful blast applied in turn to each of the two generators while steam is passing through the contents of the other.

In the press shop department great interest was shown in the manufacture of pressed steel under-frames and bogies for railway rolling-stock on Fox's system which consists of flanging in dies at one heat the various box-shaped parts peculiar to this form of construction, and which

results in a frame of great strength and durability, with exceptional lightness, coupled with the great advantage of interchangeability. A considerable quantity of material, just removed from the presses, was observable, notably parts for 400 pressed steel bogies for the Cape Government railway; and parts for 500 under-frames in course of manufacture for the London and South-Western railway; in addition to carriage under-frames of considerable length, with bogies, all in pressed steel on this system, for Indian railways. Drilling, finishing, and erecting similar frames was also seen in progress.

Another feature which received close attention was the flanging at one heat, by means of the hydraulic press mentioned, a number of combustion chamber plates, forming part of 92 plates ordered by the Russian Government, and which came from the press perfectly true and square.

Another important operation, and one which is entirely novel, having only been introduced during the present year, was the production of pressed steel axle-boxes, a number of which were pressed from a single plate to the form and dimensions required by means of suitably shaped dies. Several thousands of these were under the process of manufacture for Indian railway work.

The tour of the works having been completed, the visitors assembled to partake of refreshments before leaving the works, and a number of models illustrating the two sections of corrugated furnaces, which are made at these works, were distributed. A vote of thanks was proposed to Mr. Samson Fox and his officials by Mr. Robert Thompson, President of the Institution, supported by Mr. John Spear, President of the Hull Institute, and heartily endorsed by the whole of the visitors. Mr. Samson Fox having briefly responded, the whole party, after having spent a pleasant and instructive visit, repaired to Armley station for the return journey.

APPENDIX.

CATALOGUE OF BOOKS, TRANSACTIONS, AND PERIODICALS IN LIBRARY, JULY, 1893.

(1.) Transactions of Learned Societies.

American Society of Mechanical Engineers, New York City, N.Y., Vol. I. to date.
American Society of Naval Engineers, Navy Department, Washington, U.S. of America, Vol. I. to date.
Canadian Society of Civil Engineers, Montreal, Canada, Vol. I. to date.
Civil and Mechanical Engineers, 1888-89.
Cleveland Institution of Engineers, Middlesbrough, 1889 to date.
Engineering Association, Sydney, New South Wales, Australia, Vol. I. to date.
Engineers and Shipbuilders in Scotland, Glasgow, Vol. III. to date.
Genio Civile, Roma, Vol. XXII. to date.
Hull and District Institution of Engineers and Naval Architects, Hull, Vol. I. to date.
Institution of Civil Engineers, London, Vol. LXXIX. to date.
Iron and Steel Institute, London, 1885 to date.
Junior Engineering Society, London, 1884 to date.
Liverpool Engineering Society, Liverpool, Vol. I. to date.
Liverpool Polytechnic Society, Liverpool, 1887 to date.
Manchester Association of Engineers, Manchester, 1883 to date.
Marine Engineers, Institute of, Vol. I. to date.
Mechanical Engineers, London, 1885 to date.
Midland Institute of Mining, Civil, and Mechanical Engineers, Barnsley, 1884 to date.
Naval Architects' Institution, London, Vols. I. to IX. and XVIII. to date.
North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, Vol. XXXIV. to date.
North-East Coast Institution of Engineers and Shipbuilders, Vol. I. to date.
Philosophical Society, Glasgow, Vol. XIX. to date.
Royal Dublin Society, Dublin, *Transactions*, Vol. III. to date; *Proceedings*, Vol. IV. to date.
Society of Arts, London, Vol. XXXVII. to date.
Society of Engineers, London, 1884 to date.
Société des Ingénieurs, etc., de Liége, *Bulletin*, 1885 to date; *Annuaires*, 1885 to date.
Société Scientifique de Marseille, Vol. I. to date.
South Wales Institute of Engineers, Swansea, 1884 to date.
United States Naval Institute, Annapolis, Maryland, U.S. of America, 1886 to date.

(2.) Technical Journals and Periodicals.

Electrical Engineer, London, Vol. III. to date.
Electrical Review, London, Vol. XXIV. to date.
Engineering, London, Vols. IV., V., and VI., XX. and XXI., XXXIV. to date.
Indian Engineer, Calcutta, British India, Vol. VII. to date.

Indian Engineering, Calcutta, British India, Vol. III. to date.
Industries, London, Vol. I. to date.
Inventions, London, Vol. XI. to date.
Iron, London, 1888 to date.
Iron and Coal Trades Review, London, Vols. XXXVI. and XXXVII. only.
Journal de La Marine le Yacht, 1892 to date.
Marine Engineer, London, Vol. VII. to date.
Mechanical World, Manchester, 1886 and 1889 to date.
Rivista Marittima, Vol. I. to date.
Shipping World, London, Vol. IV. to date.
Stahl und Eisen, Düsseldorf, Vol. IX. to date.
The Electrician, London, Vol. XXXI.
The Engineer, London, Vol. LIX. to date.
The Mechanics' Magazine, 1864-1866 (3 vols.).
The Practical Engineer, Manchester, Vol. I. to date.
The Practical Mechanics' Journal, 1863 to 1870 (4 vols.).
The Steamship, London, Vols. I. and II.
The Steamship, Leith, Vol. I. to date.
Transport, London, Vol. II. to date.

(3.) General.

(a.) *Engineering and Mechanical.*

Applied Mechanics ...	Prof. Rankine	1888
Do.	J. H. Cotterill	1890
Boilers and Boiler Making ...	N. P. Burgh	1873
Boilers, their Construction and Strength...	T. W. Traill	1888
Bridge Construction	T. C. Fidler	1887
Bureau of Steam Engineering (U.S.A.), Report of		1889-90
Bureau Veritas—Report on Steel ...		1878
Chemical Analysis of Iron ...	Blair	1891
Civil Engineering ...	Prof. Rankine	1889
Elements of Machine Design (2 vols.)	Unwin	1891
Engine and Boiler Trials ...	R. H. Thurston	1890
Engineering (British Association)...	W. Boyd	1889
Engineering Education in the British Dominions		1891
Engineering Facts and Figures (2 vols., 1863 and 1864)...	A. B. Brown	1865
Engineering Popularly and Socially Considered (2 copies)	J. W. C. Haldane	1890
Engineer's Handbook	T. Reed	1889
Engineers' Price Book	Spon	1892-93
Friction and Lost Work in Machinery and Millwork ...	R. H. Thurston	1889
Gas Engine ...	D. K. Clark	1890
Gas and Petroleum Engines	Robinson	1891
Graphic Statics, Principles of	G. S. Clark	1888
Heat, Treatise on ...	T. Box	1888
Heat: A Mode of Motion ...	J. Tyndall	1887
Hydrology, Manual of	W. Beardmore	1872
Hydraulic Power and Hydraulic Machinery		1887
Hydraulic Motors ...	Bodmer	1889
Iron Bridge Construction (2 vols.)	W. Humber	1870

Iron and Steel Industries, Report on, in Foreign Countries ...		
Iron Roofs	A. T. Walmsley	1888
Machinery and Millwork	Prof. Rankine	1887
Manual of Marine Engineering	A. E. Seaton	1889
Manufacture of Iron and Steel, Principles of	I. L. Bell	1884
Marine Engineering (2 vols.)	W. H. Maw	
Marine Propellers (3 copies)	S. W. Barnaby	1891
Marine Steam Engine	R. Sennett	1885
Materials of Engineering (3 vols.)...	R. H. Thurston	1884
Mechanician, The	Knight	1888
Mechanical Graphics	G. Halliday	1889
Mechanical Text Book	Prof. Rankine	1884
Mechanical Engineers' Reference Book	N. Foley	1891
Mechanics of Machinery	Kennedy	1886
Metallurgy of Iron, Treatise on	H. Bauerman, F.G.S.	1890
Metallurgy of Steel	H. M. Howe	1890
Metallurgy	Phillips & Bauerman	1891
Metals: Their Properties and Treatment...	C. L. Bloxham	1885
Mill Gearing, etc.	T. Box	1888
Modern French Artillery	Dredge	1892
Modern Marine Engineering (2 vols.)	N. P. Burgh	1872
Pocket Book on Boilers	T. W. Traill	1888
Report of Boiler Committee		1893
Rules and Tables	Prof. Rankine	1889
Rules, Tables, and Data for Mechanical Engineers	D. K. Clark	1890
Screw Propeller	W. Bourne	1867
Slide Valve	N. P. Burgh	1868
Steam and the Steam Engine, Text Book on	A. Jamieson	1889
Steam Engine	G. C. V. Holmes	1890
Do. (4 vols.)	D. K. Clark	1890
Do.	J. H. Cotterill	1890
Steam Boilers	R. Wilson	1879
Do.	R. H. Thurston	1888
Steam Engine	Prof. Rankine	1888
Steam Engine and the Indicator	Le Van	1890
Strains in Structures	G. A. T. Middleton	1889
Strength of Materials	T. Box	1888
Do. do.	Unwin	1888
Strength of Iron Parts of Steam Machinery	Van Buren	1869
Strength of Beams and Columns	Cousin	1889
Structures, Design of	Anglin	1891
Substitution of Metal for Wood in Railway Ties, Report on ...	B. E. Fernow	1890
Testing Materials of Construction	W. C. Unwin	1888
Theory of Stresses	B. B. Stoney	1886
Turbine, The	W. Cullen	1871
Valve Gears	J. F. Klein	1884
Wire, Its Manufacture and Uses	J. B. Smith	1891

(*b.*) *Shipbuilding, etc.*

Annals of Lloyd's Register		1884
British Corporation for the Survey and Registry of Shipping ...	Glasgow	1893
Bureau Veritas Register of Shipping		1887 to date

German Lloyd's International Register of Shipping		1891 to date
German Lloyd's Rules and Regulations		1891 „
Illustrated Marine Encyclopedia	H. Paash	1890
Lloyd's Register of British and Foreign Shipping (2 vols.) ...		1891 to date
Lloyd's Rules and Regulations		1891 „
Modern Shipbuilding and the Men Engaged in it	D. Pollock	1884
Naval Architecture, Manual of	W. H. White	1889
Naval Annuals	Lord Brassey	1886, 1887, 1890, to date
Report of the Committee on the Spacing and Construction of Watertight Bulkheads		1891
Shipbuilding Theoretical and Practical	Prof. Rankine	1866
Shipbuilding (2 vols.)	Thearl	1886
Shipping World Year Book		1887
Stability of Ships	Sir E. J. Reed	1885
Do.	J. C. Spence	1884
Steam Navigation	B. Woodcroft	1848
Yacht and Boat Sailing	D. Kemp	1891
Yacht Architecture	„	1891

(*c.*) *Electrical.*

Dynamos, Alternators, and Transformers...	Kapp	1893
Dynometers and the Measurement of Power	Hather	1892
Dynamo Electric Machinery	Thompson	1892
Dynamo Electric Machines...	Hering	1890
Electro Magnet	Thompson	1891
Electricity and Magnetism (2 vols.)	J. C. Maxwell	1881
Elementary Treatise on do....	„	1881
Electricity and Magnetism, First Book of	W. P. Maycock	1891
Electric Light Fitting	J. W. Urquhart	1890
Electric Transmission of Energy	G. Kapp	1890
Engineer's and Contractor's Book of Prices	Spon	1892-3
Experimental Researches in Electricity (3 vols.)	M. Faraday	1839
Practical Electrical Engineering	C. H. W. Biggs	1893
Practical Electrical Measurement	J. Swinbourne	1888
Practical Electricity	Ayrton	1889
Short Lectures to Electrical Artizans	J. A. Fleming	1890
Telephone Handbook	J. Pool	1891

(*d.*) *Miscellaneous, etc.*

Chemistry	Bloxham	1890
Collieries and Colliers	J. C. Fowler	1869
Dechane's Natural Philosophy		1891
Duties of Executors...	F. W. Dendy	1889
Elements of Projective Geometry	Cremona	1885
Foreign Office List		1886
Geology of England and Wales	H. B. Woodward	1887
Handbook to Industries, N. E. District of England	W. Richardson	1889
Imperial Journal (3 vols.)		
Industrial Resources of the Tyne, Wear, and Tees...	Lord Armstrong and others	1864
Management of an English Railway	G. Findlay	1891
Marine Transport of Petroleum	Little	1890

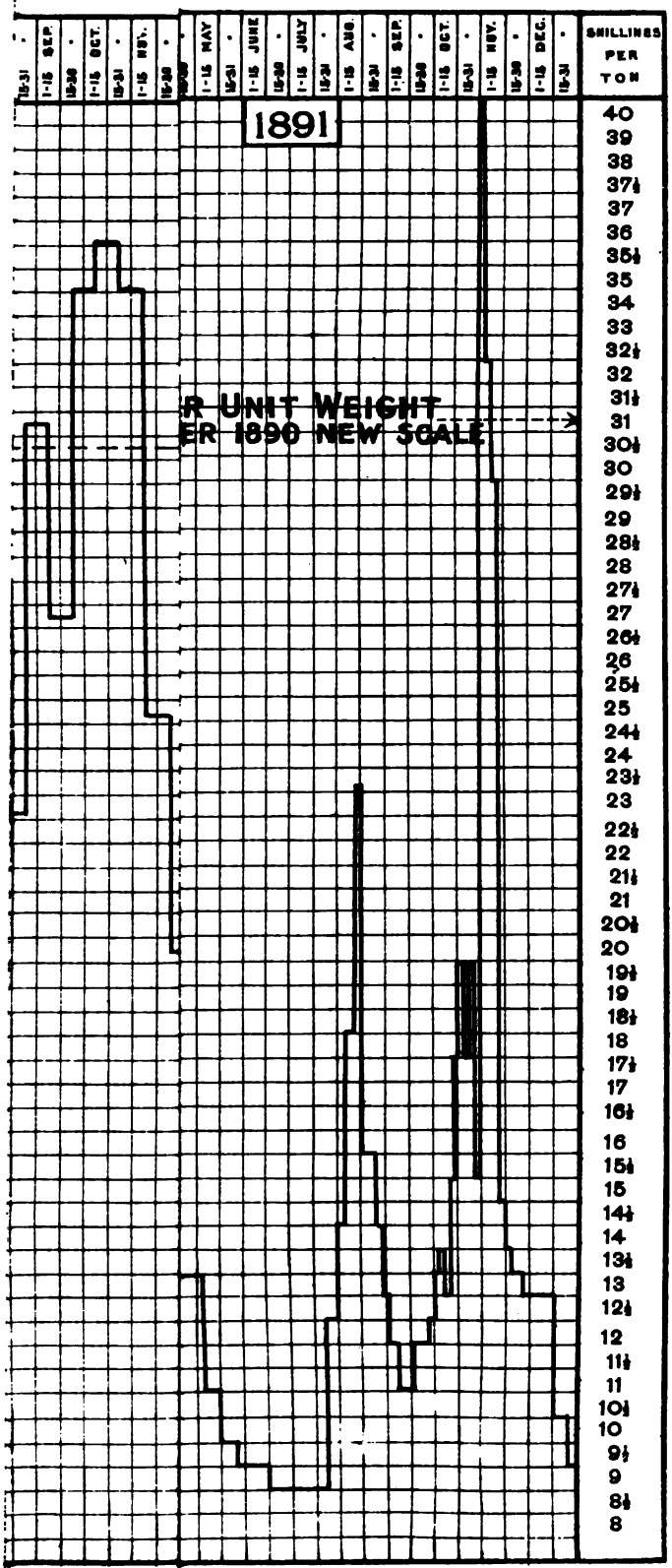
Miscellaneous Scientific Papers	Prof. Rankine	1881
Practical Treatise on Petroleum	B. J. Crew	1887
Record of the International Exhibition, London...		1862
River Tyne, History and Resources of	J. Guthrie	1880
Service Chemistry	V. B. Lewes	1889
Water-Gas Plant, a description of	S. Fox	1888
Water Ways and Water Transport	Jeans	1890
Year Book of Scientific Societies	1890 to date	

(*e.*) *Biographical.*

Lives of Brindley and others	Smiles	1874
„ Boulton and Watt	„	1878
„ William Denny	A. B. Bruce	1889
„ Metcalf and Telford	Smiles	1874
„ James Nasmyth	„	1885
„ Smeaton and Rennie	„	1874
„ G. and R. Stephenson	„	1879
„ R. Trevethick	F. Trevethick	1872

(*f.*) *Dictionaries.*

Dictionary of Engineering (4 vols.)	Spon	1874
Dictionary of Terms relating to Iron	A. Tolhausen	1870
French and English Dictionary (2 vols.)	L. Smith & H. Hamilton	1882
German and English Dictionary	Theime-Preusser, E. Wesseley	
Italian and English Dictionary (2 vols.)	Millhouse	
Spanish and English Dictionary	Bustamantes	1890
Technological Dictionary (3 vols.)	A. Tolhausen	1883



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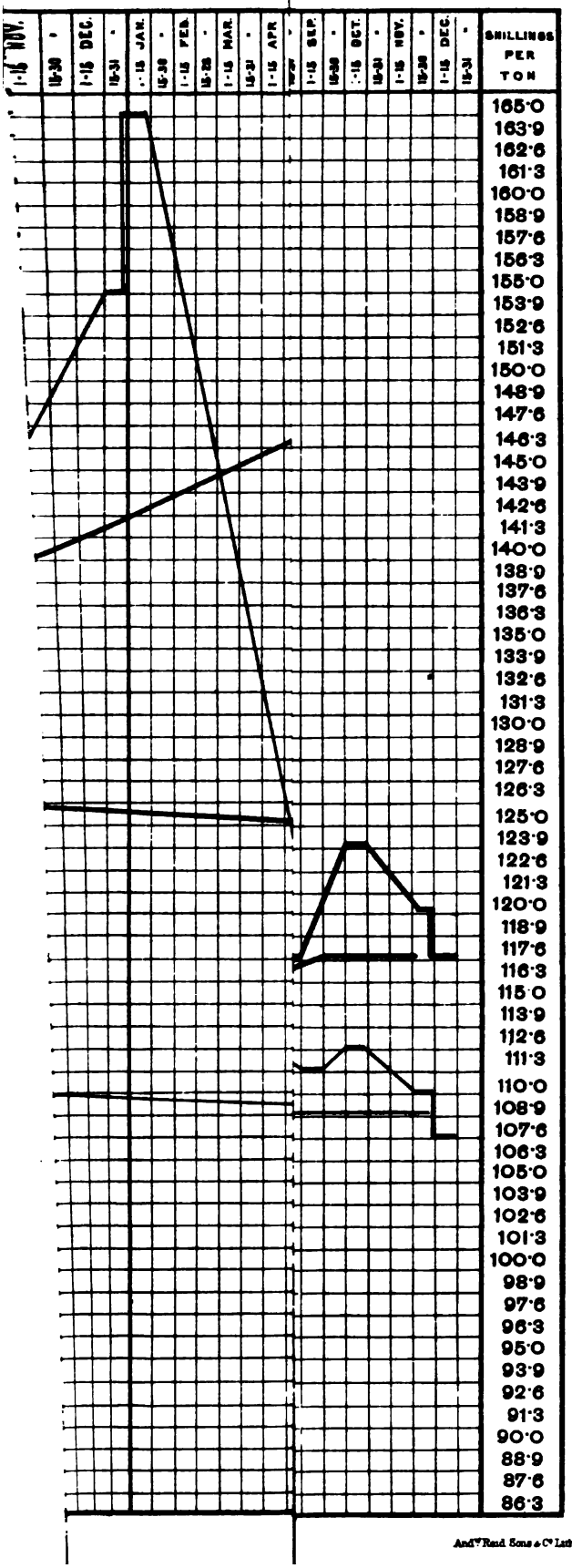

And^w Reid Sons & Co Lithos Newcastle

To illustrate Mr. Fothergill's Paper on "The Combustion of Coal & Prevention of Smoke."

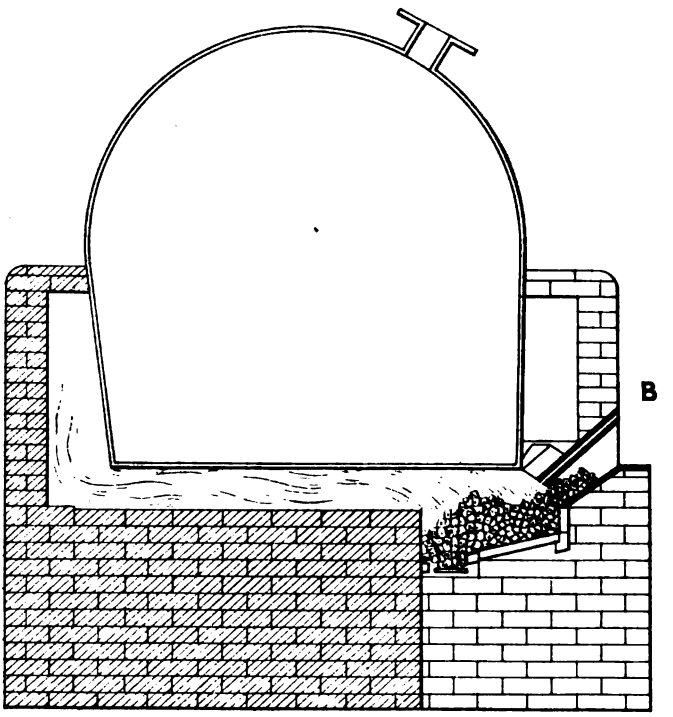

FIG. I.

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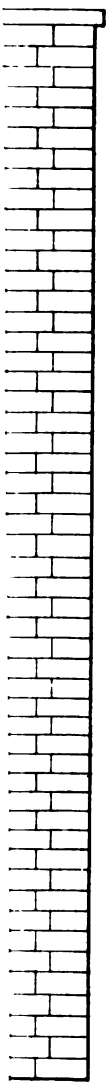

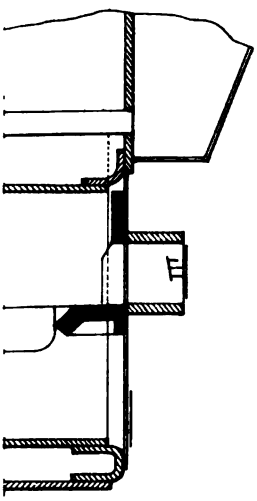

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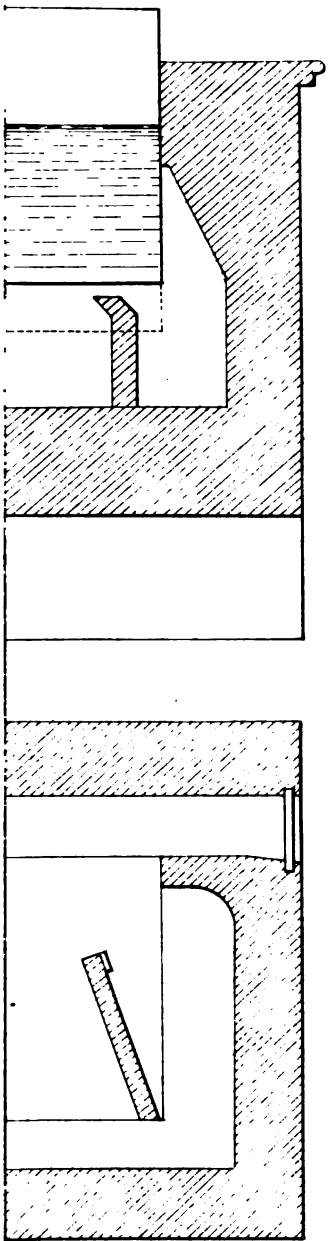

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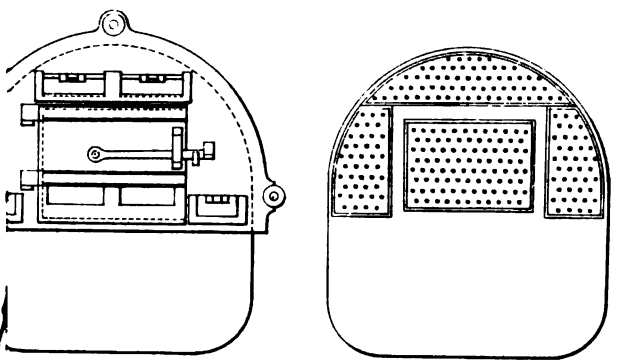

Fig. 7.

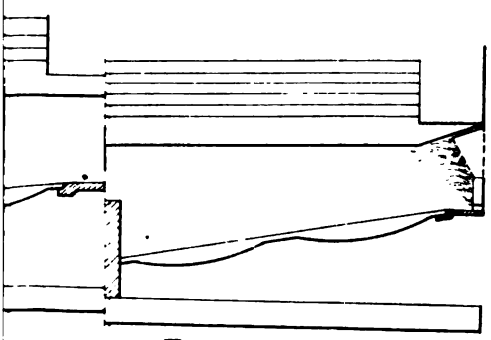

Fig. 6.

Andw Reid Sons & Co Lithos Newcastle

lustrate Mr. Fothergill's Paper on "The Combustion of Coal & Prevention of Smoke".

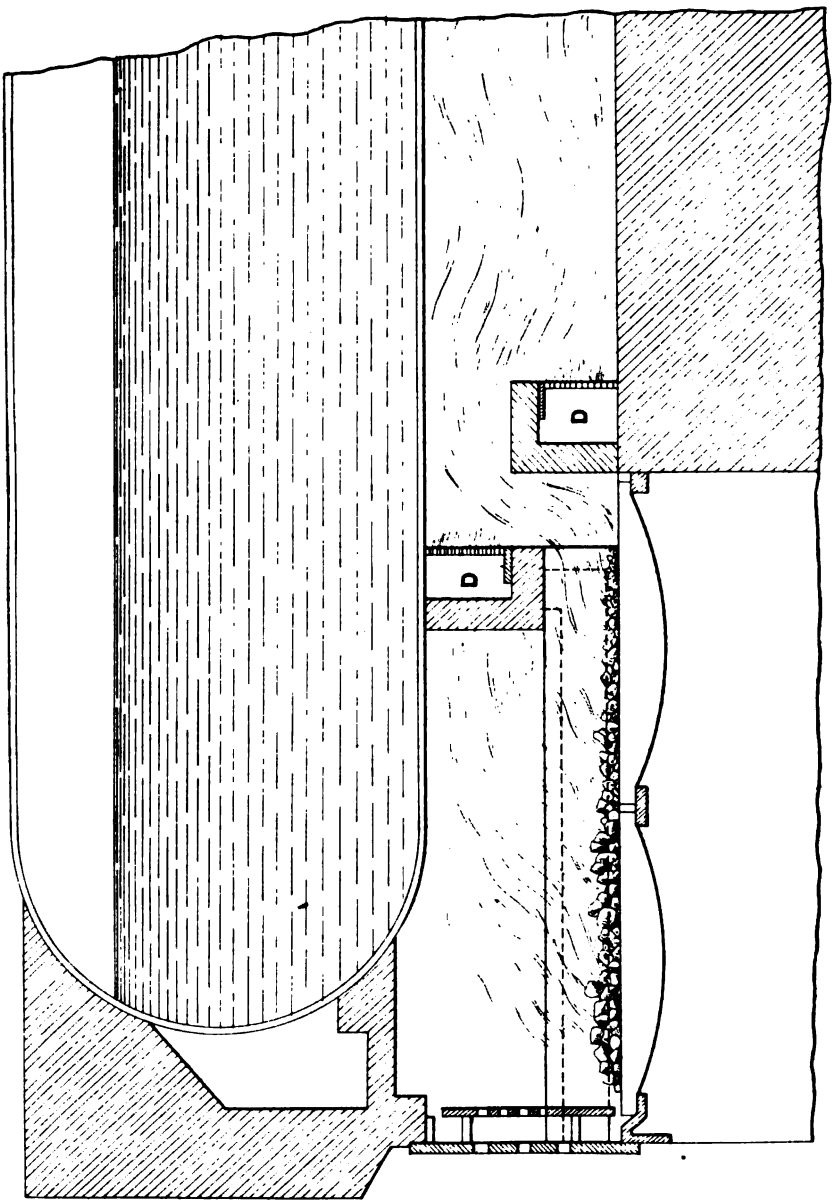

FIG. I.

And^w Reid, Sons & C. Lithos Newcastle

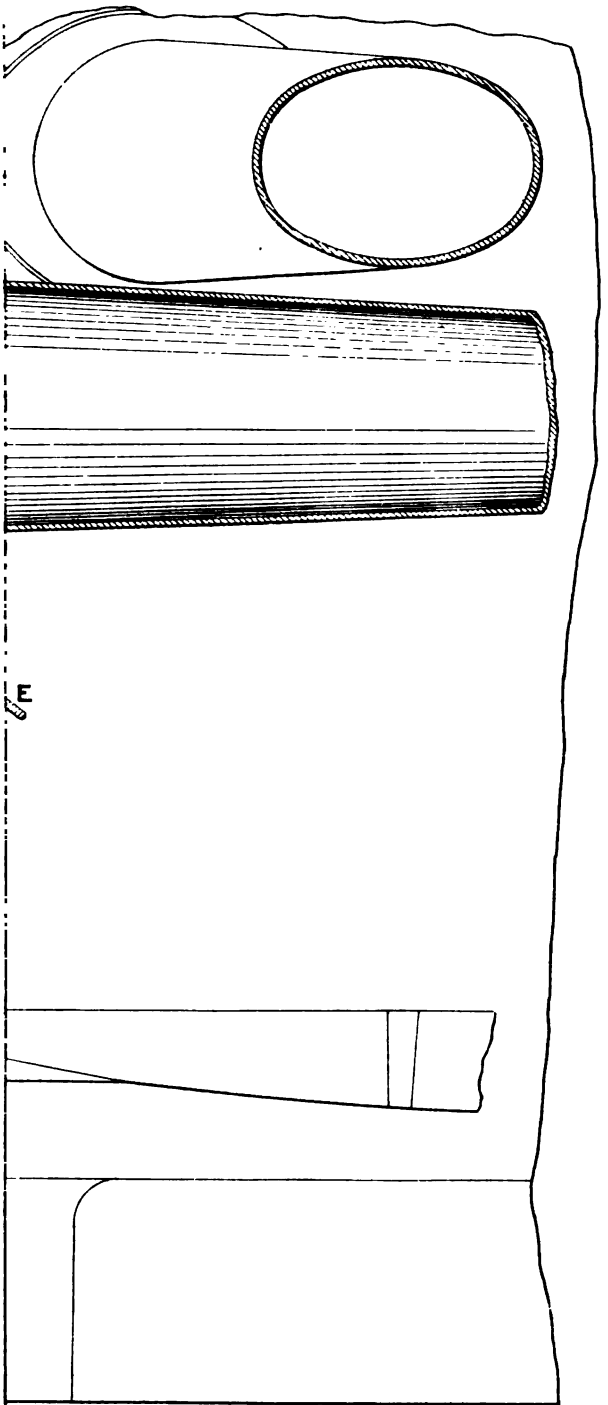

FIG. 2.

And^w Reid Lith. Newcastle

Illustrate Mr. Fothergill's Paper on "The Combustion of Coal & Prevention of Smoke."

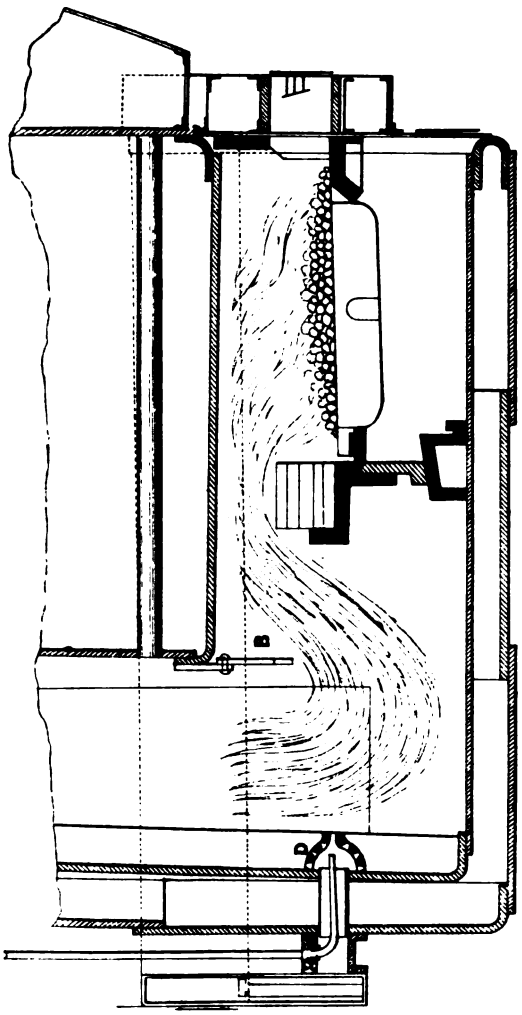

FIG. 1.

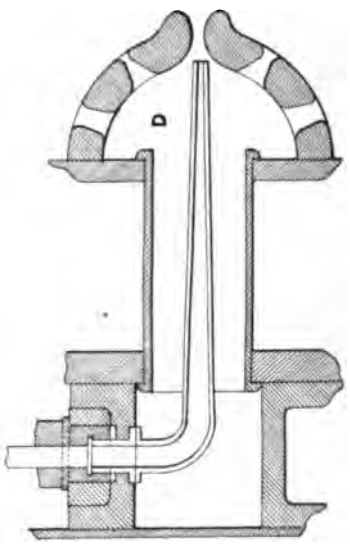

FIG. 2.

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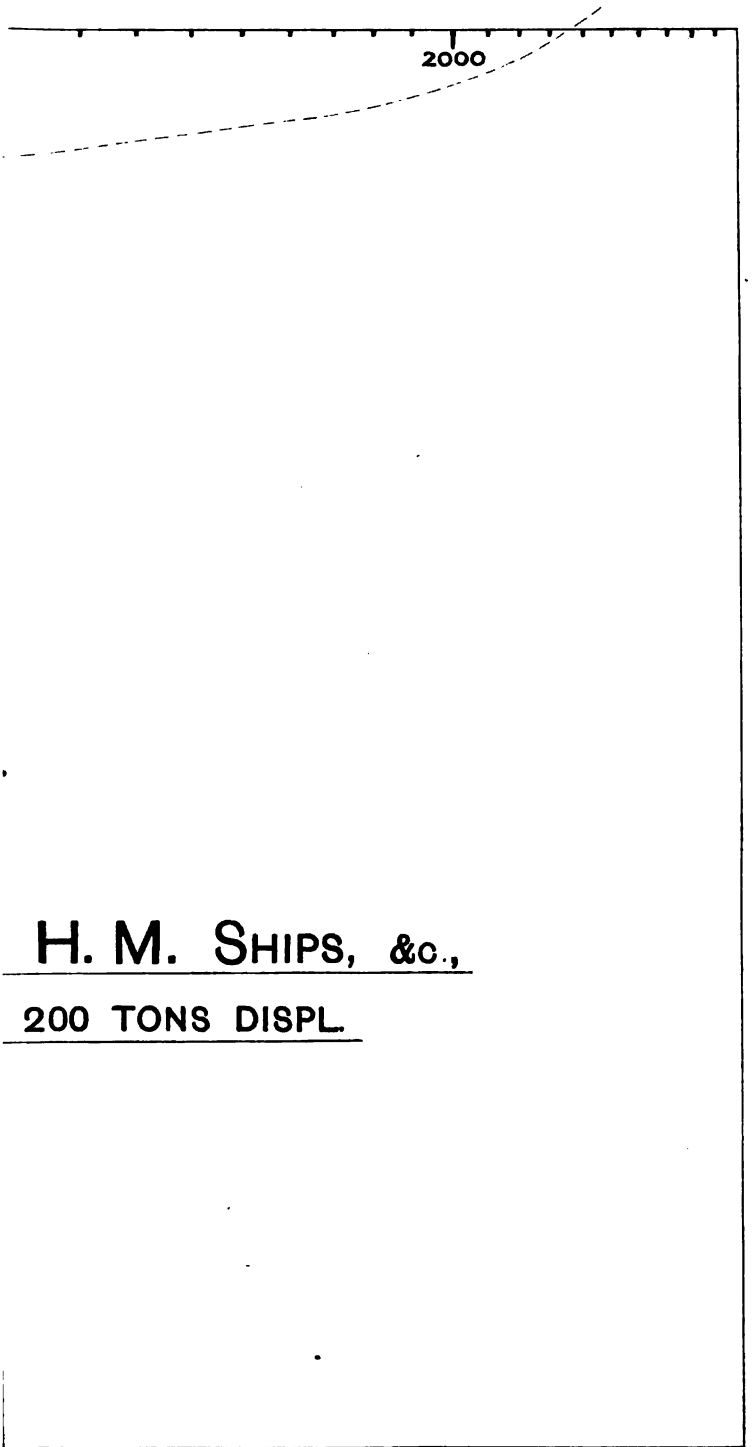
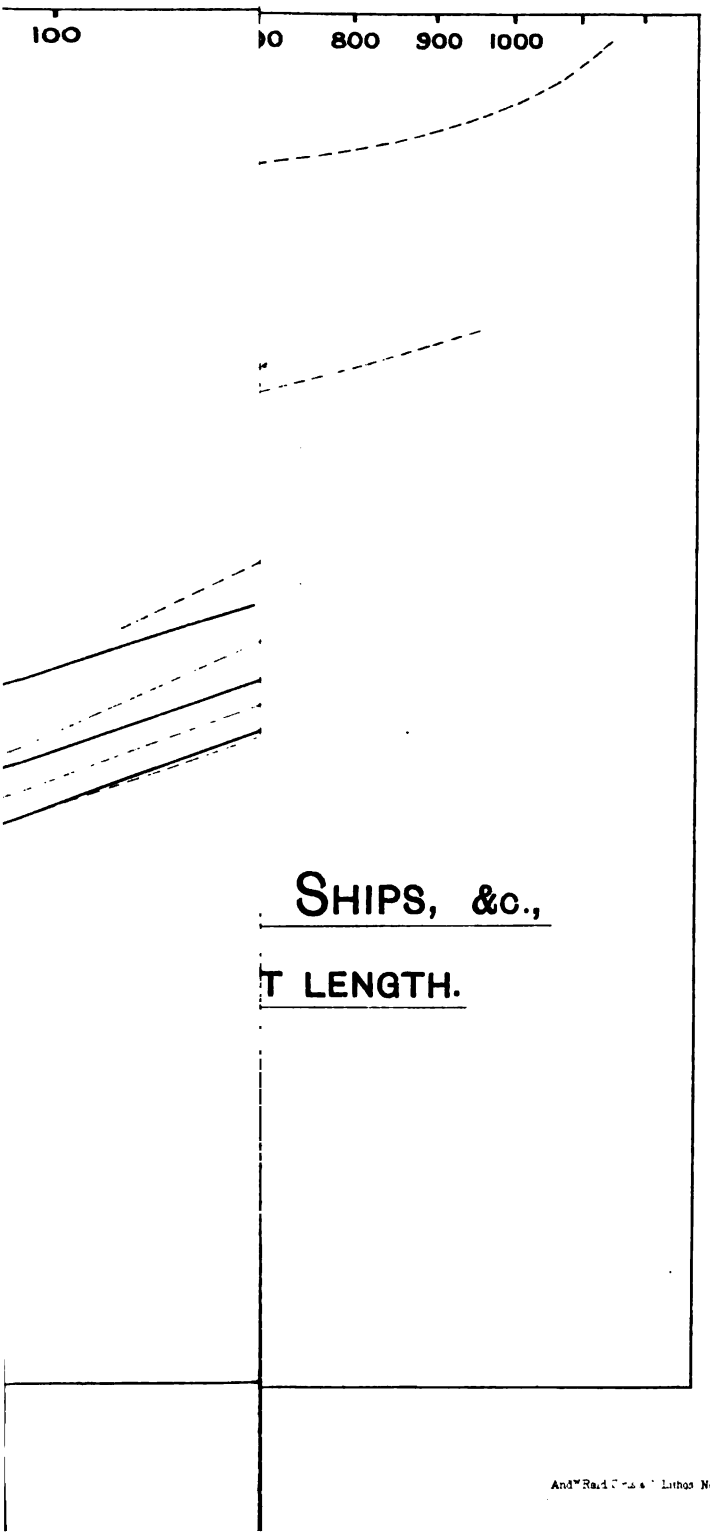
And.w Reid Sons & Co. Lithos Newcastle



H. M. SHIPS, &c.,

200 TONS DISPL.

And^w Reid Sons & Co Lithos Newcastle



And^w Reid Lith^o Newcastle

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MESSRS. HALL, RUSSELL & CO.'S EXPERIMENTS
SECTION OF FURNACE FORMED WITH ADAMSON'S RINGS.

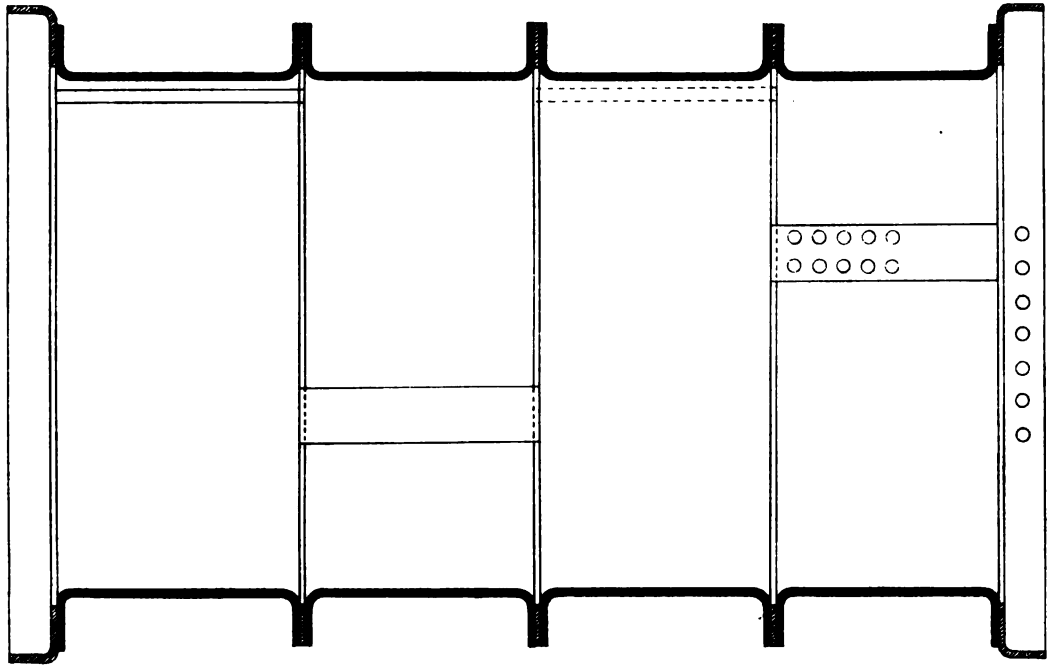

FIG. I

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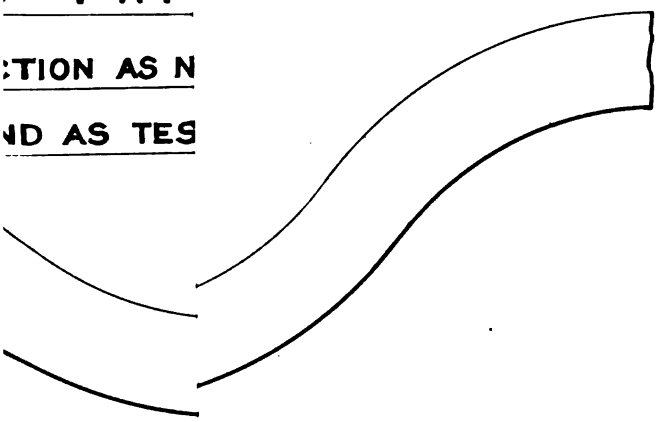

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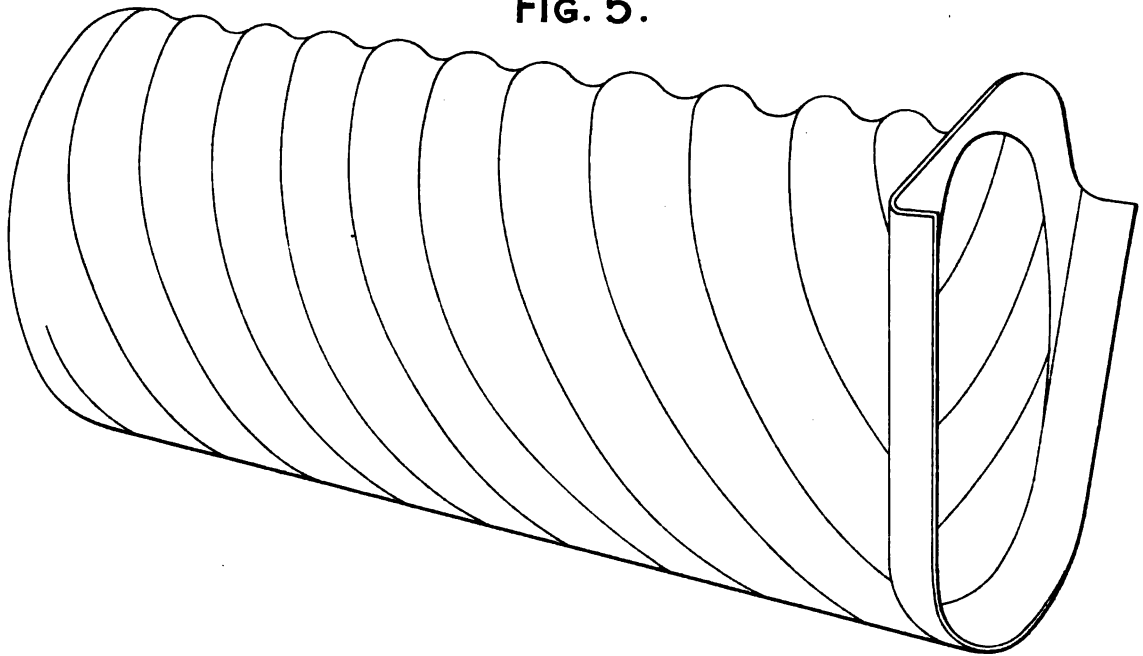
And^w Reid Sons & Co^y Lithos Newcastle

To illustrate Mr. D. B. Morison's Paper on "Marine Boiler Furnaces."

FARNLEY PATENT FURNACE.

FIG. 5.



And^w Reid Sons & Co^y Lithos Newcastle

HOLMES' PATENT FURNACE.

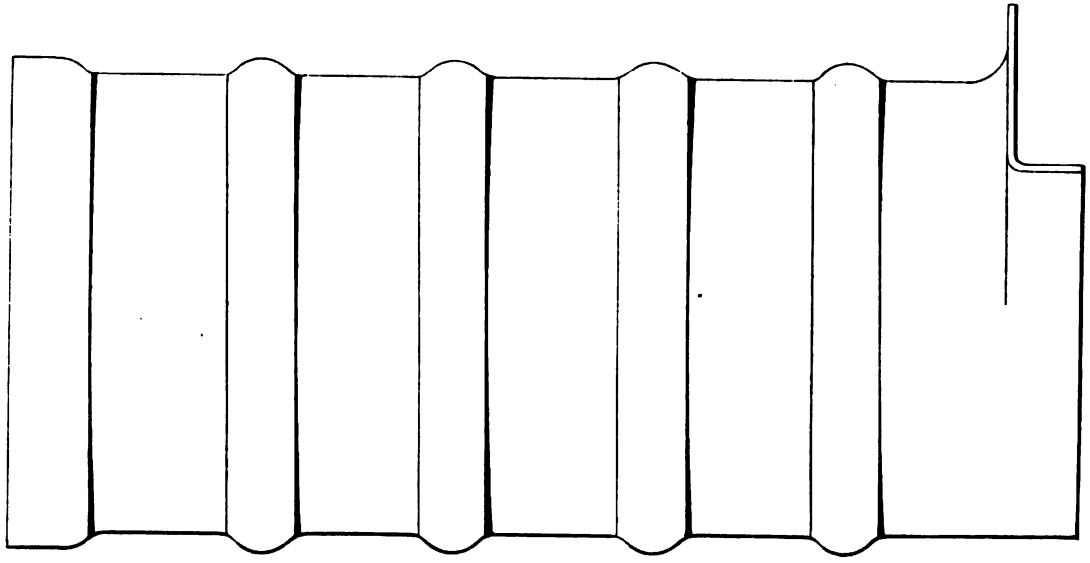


FIG. 6

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Session IX.

And^w Reid Sons & Co Lithos Newcastle

SECTION OF PURVES' PATENT FURNACE IN TESTING APPARATUS.

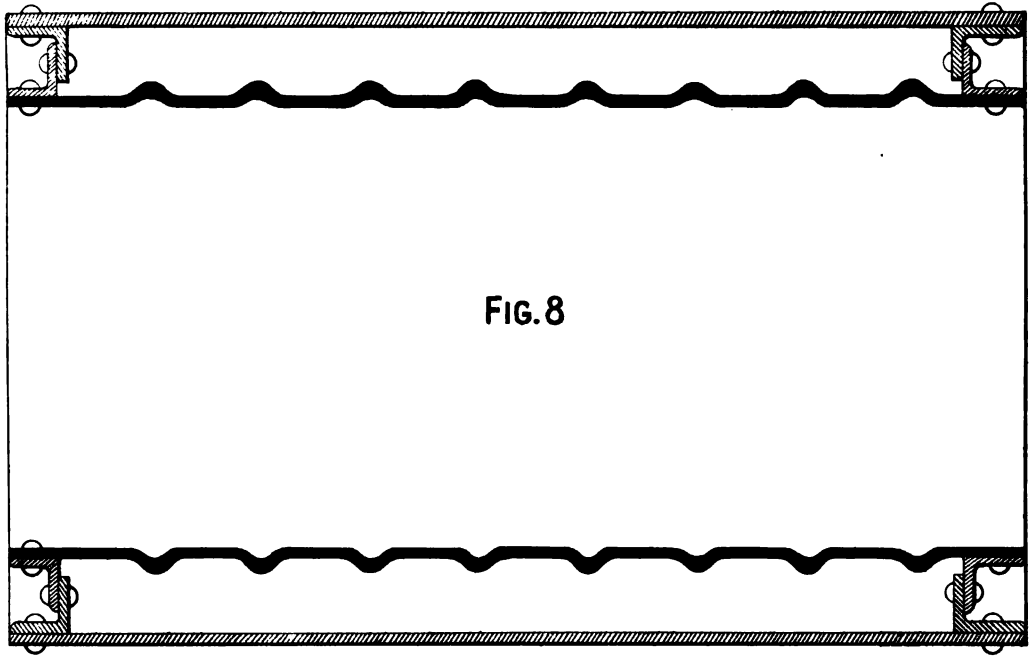

FIG. 8

...edings N E C I of E & S 1892-93.
Session IX.

1887 BOARD OF TRADE EXPERIMENTS.

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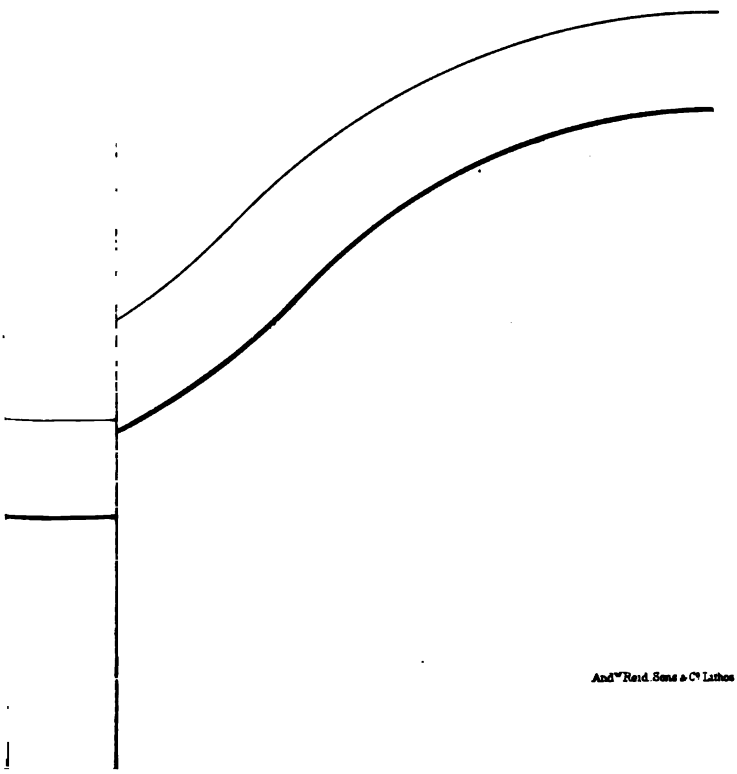

Andw Reid, Sons & Co Lithos Newcastle

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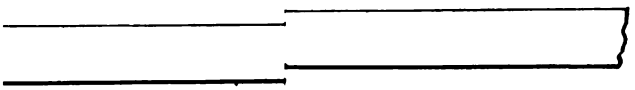

Fig. 9.

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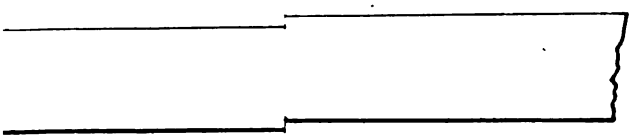

Fig. 10.

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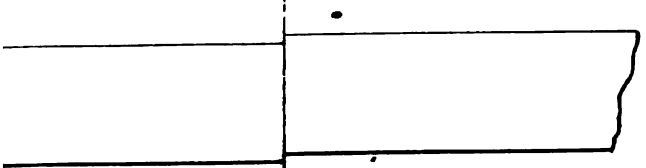


Fig. 11.

And^w Reid Sons & Co Lithos Newcastle

SECTION OF MORISON'S SUSPENSION FURNACE IN TESTING APPARATUS.

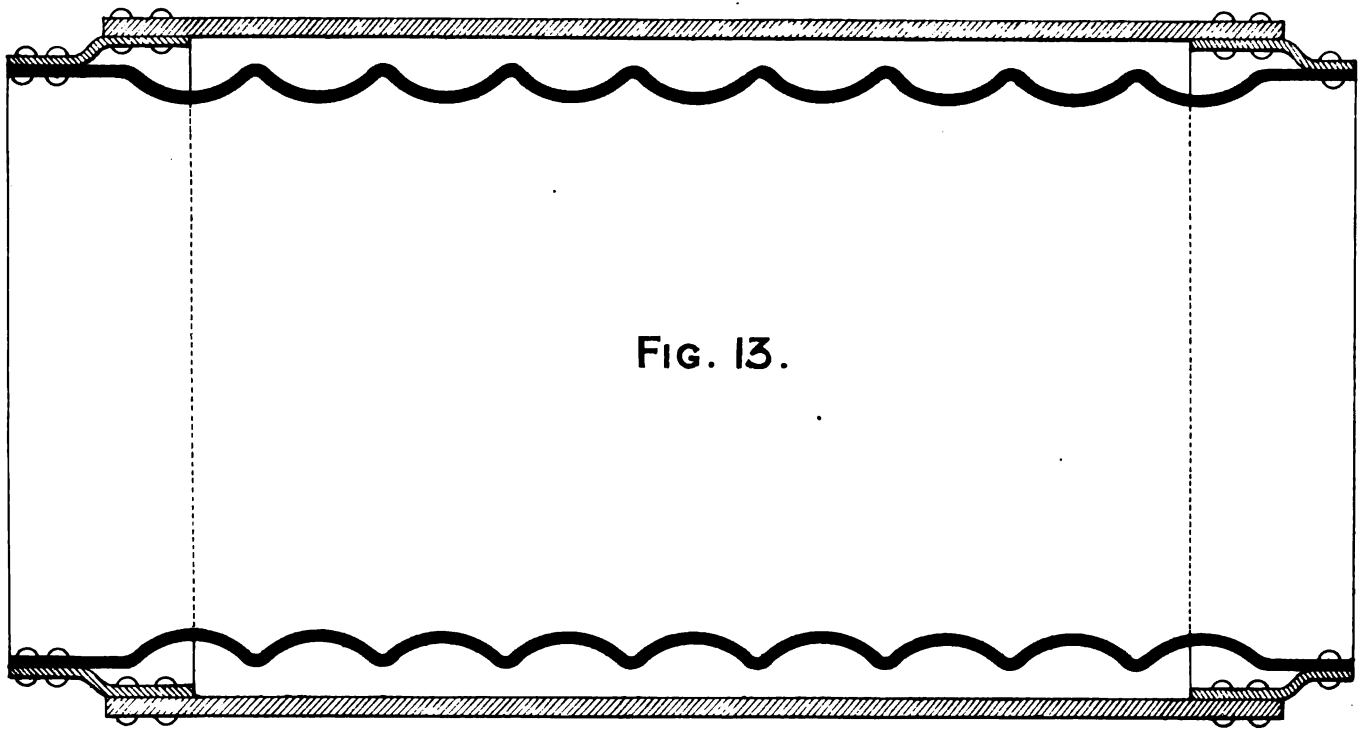


FIG. 13.

1891 BOARD OF TRADE EXPERIMENTS.

And^w Reid Sons & Co Lithos Newcastle

MORISON'S SUSPENSION FURNACE,

ARRANGED FOR REMOVAL ON ASHLIN'S PLAN.

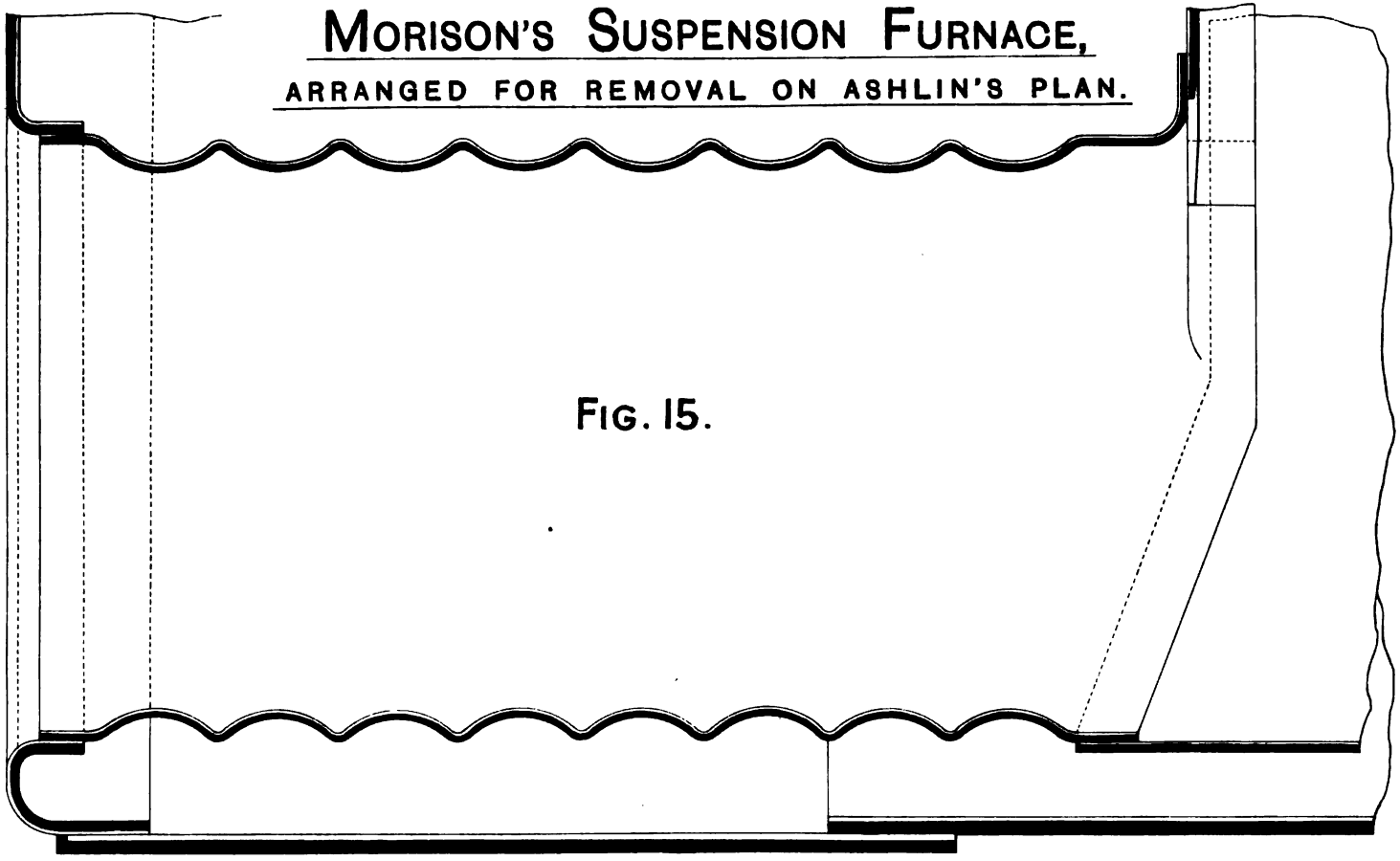
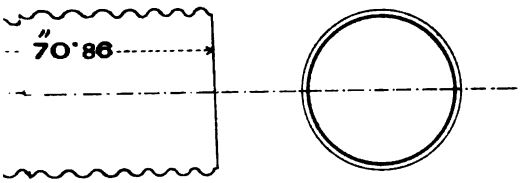
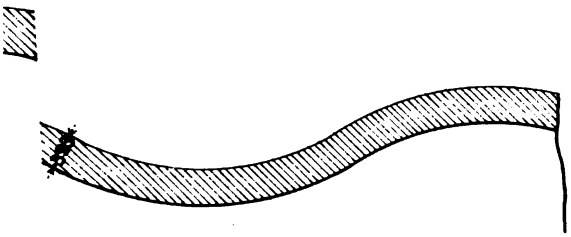


FIG. 15.

And^w Reid Sons & Co^y Lithos Newcastle





EXPERIMENT No. V.	
rest Outside Diameter - -	41·45
r Inside Diameter - - -	39·09
ile Strength of Steel - -	24·3
gation of Steel - - - -	26%

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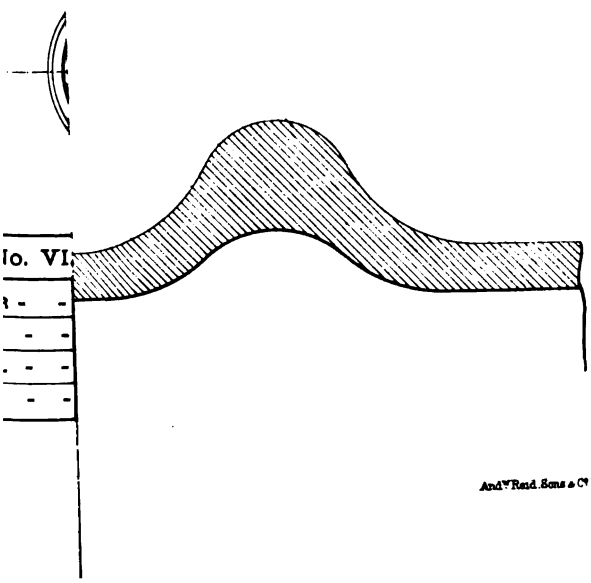

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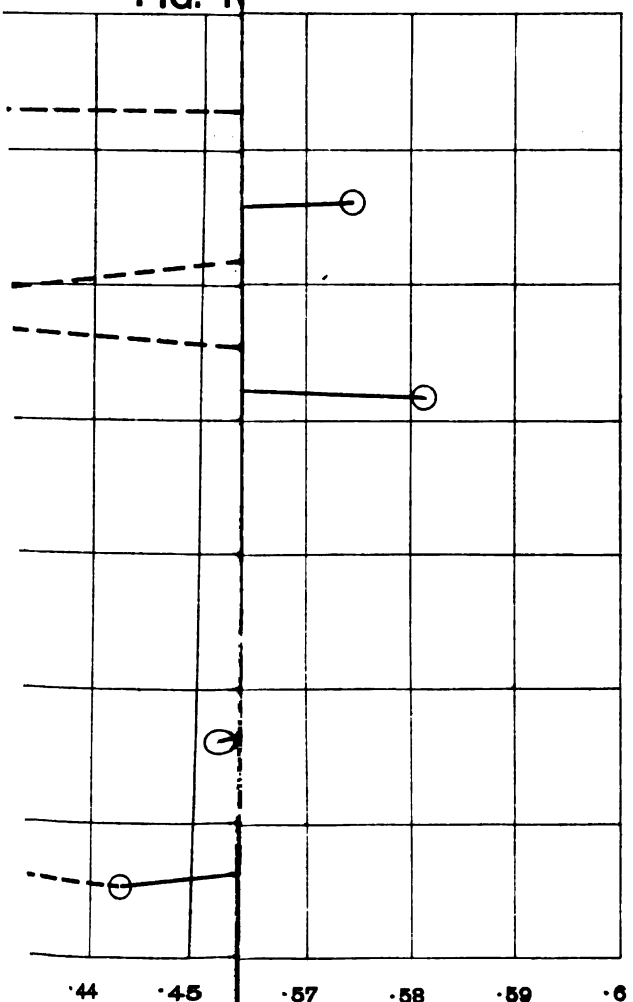

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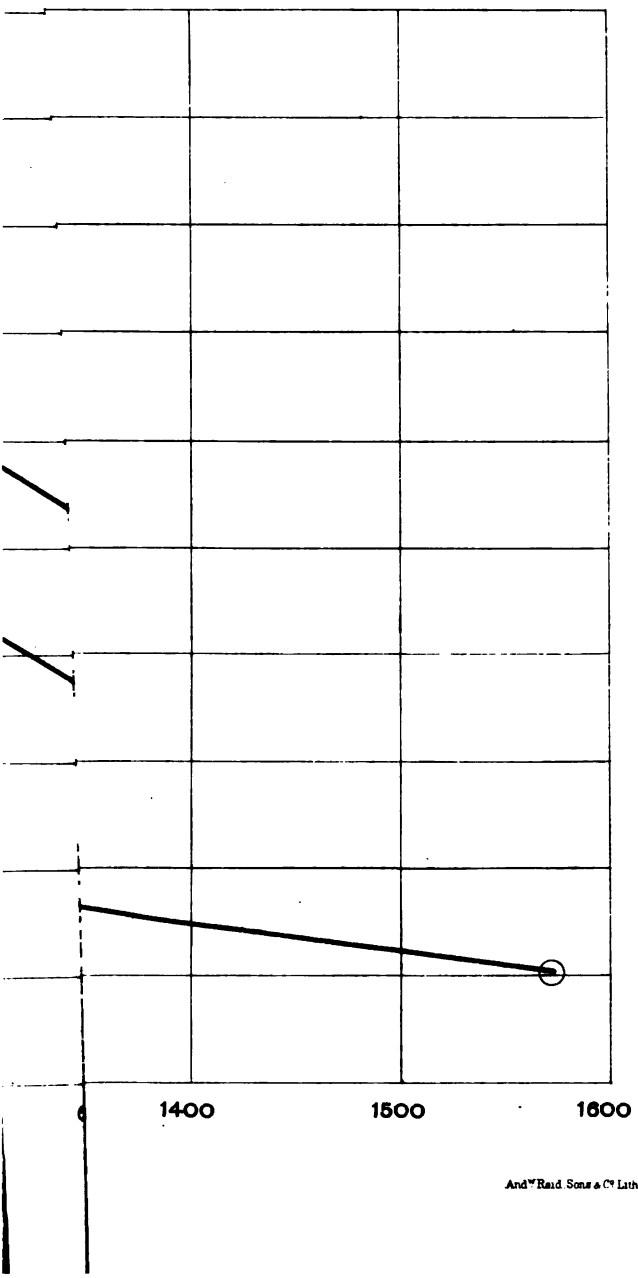

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Vol. IX. Plate XXXIV

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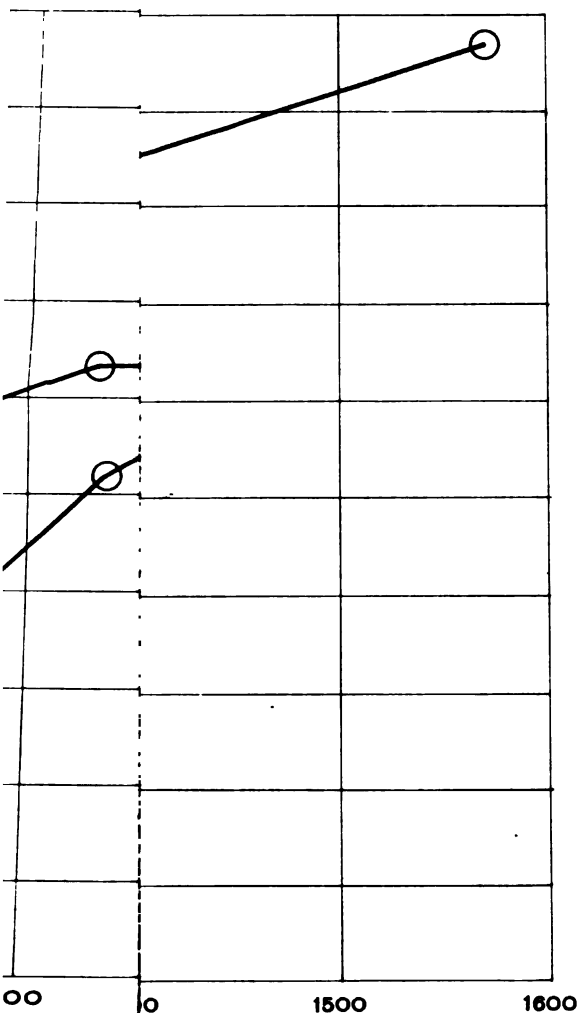

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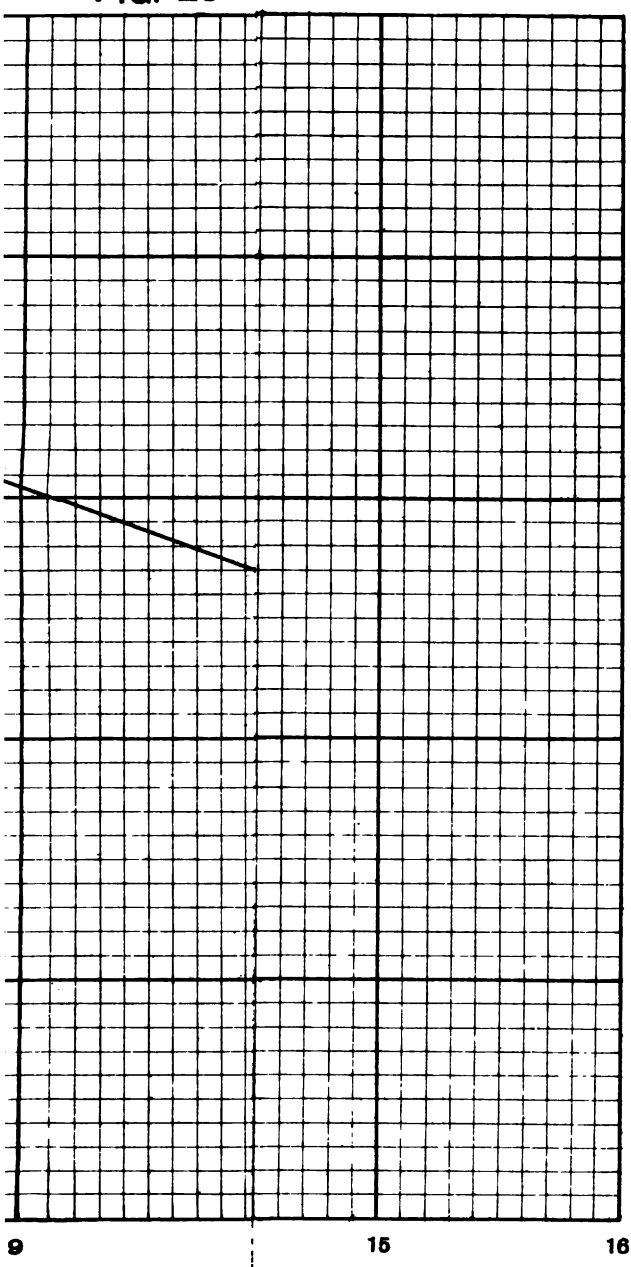
FIG. 23.



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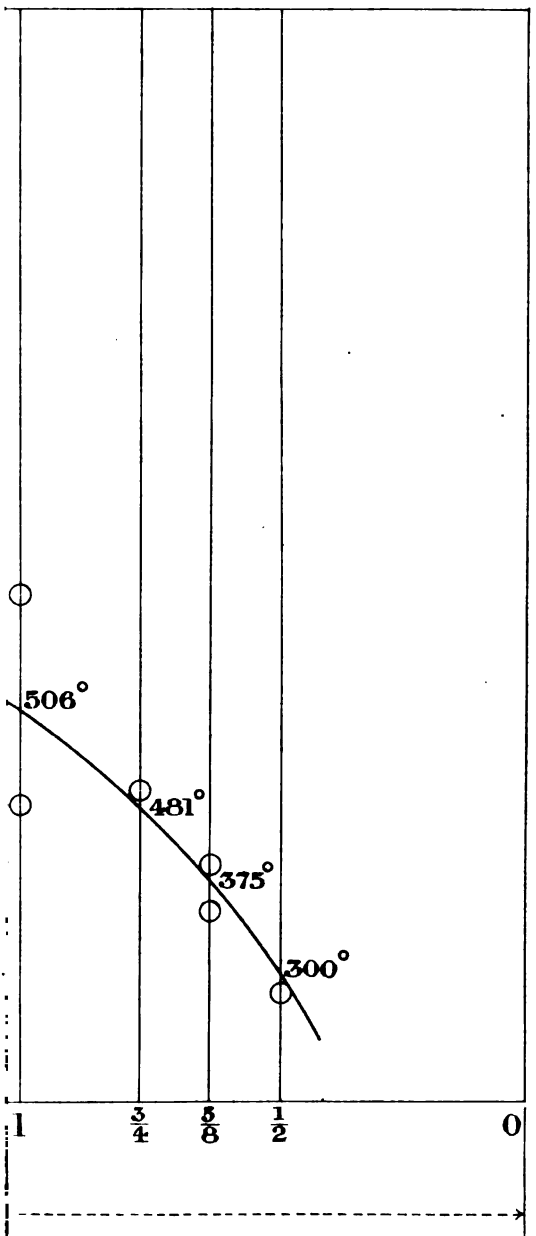

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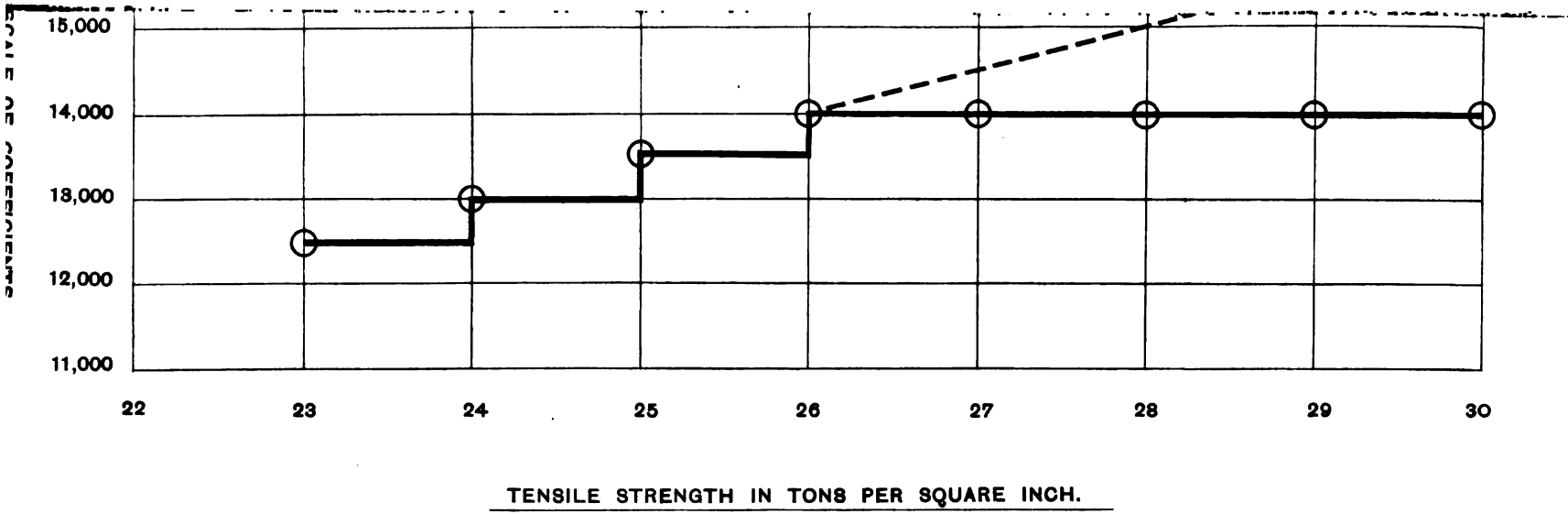
To illustrate Mr. D. B. Morison's Reply to the "Discussion on his Paper."



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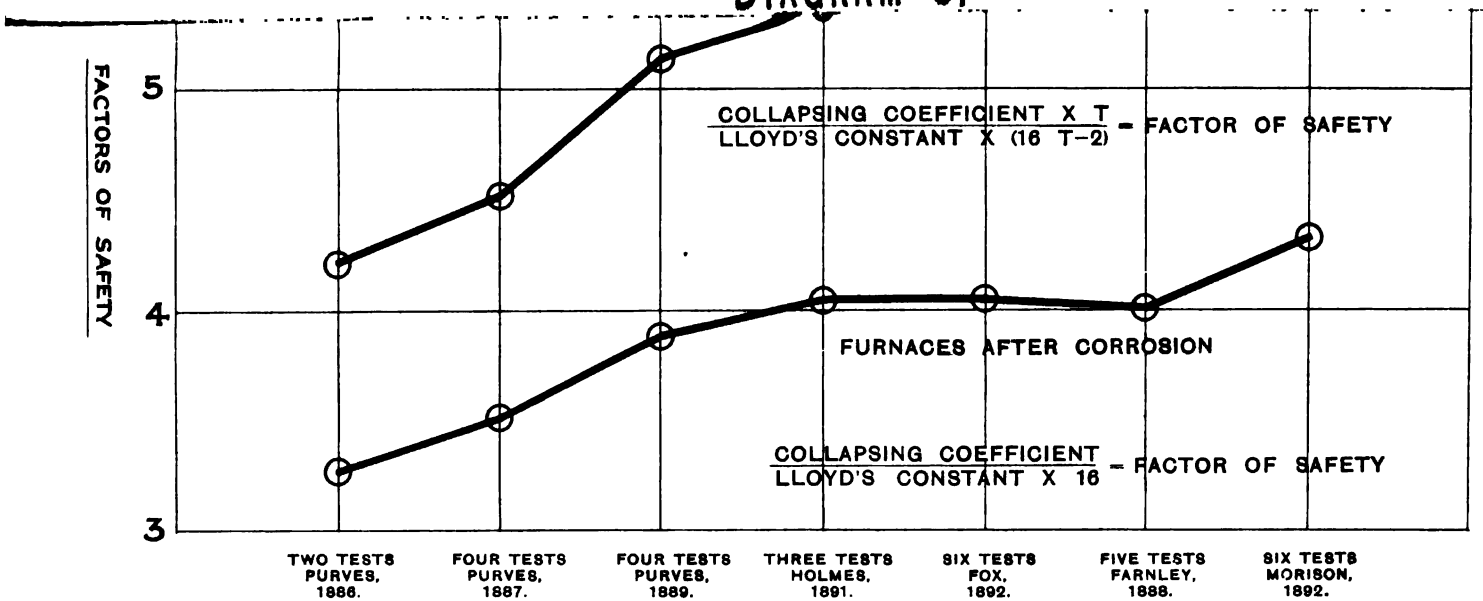
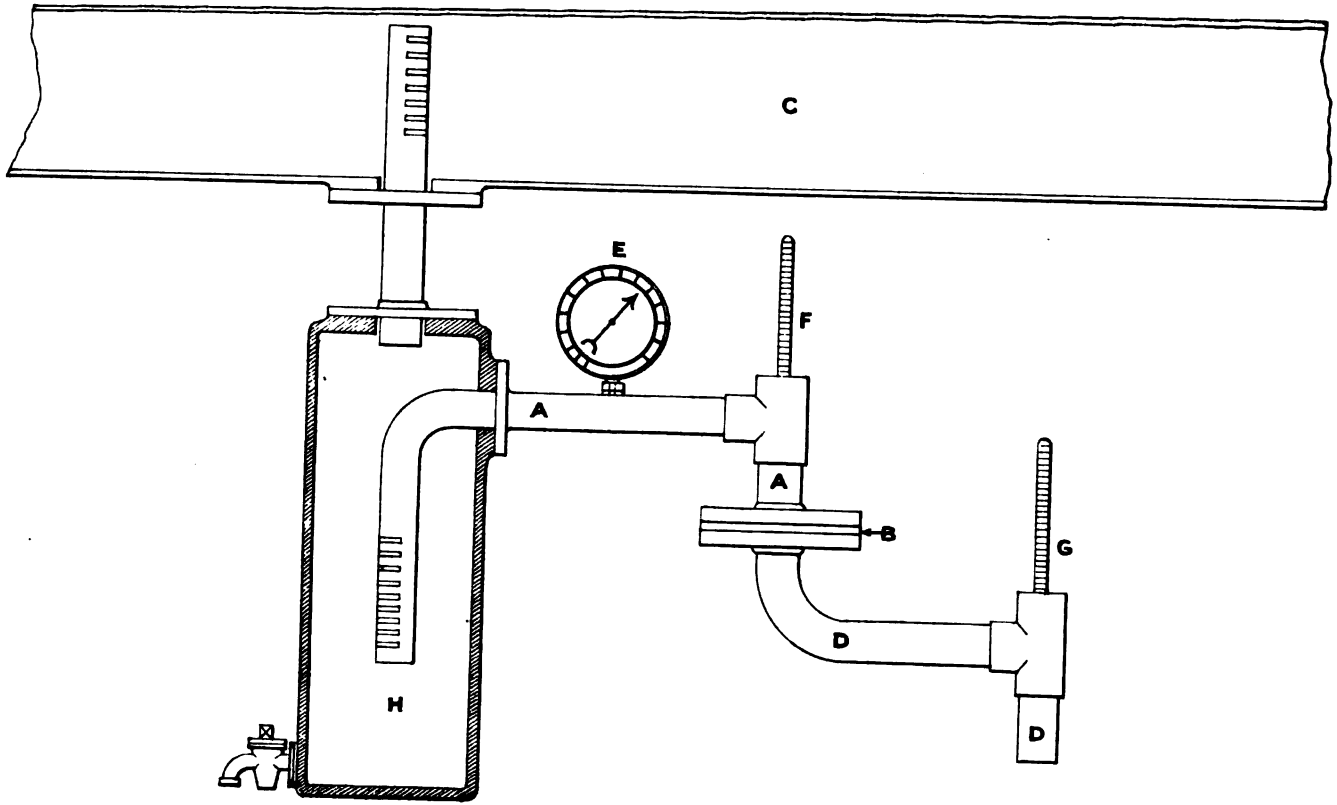
To illustrate Mr D. B. Morison's Reply to the "Discussion on his Paper"

DIAGRAM C.



FACTORS CALCULATED ON STEEL HAVING A COMMON TENSILE STRENGTH OF 27·2 TONS PER SQUARE INCH.

And.w Reid Sons & Co. Lithos Newcastle



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Session IX.

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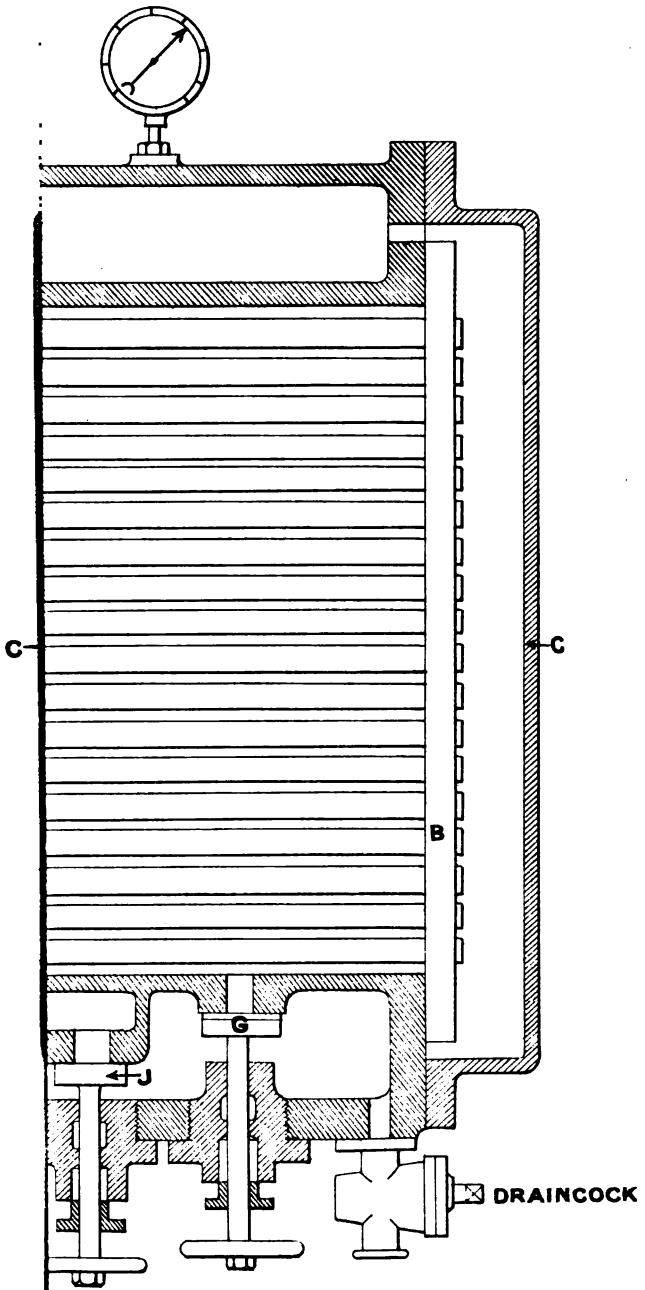
"Water suspended in Steam."



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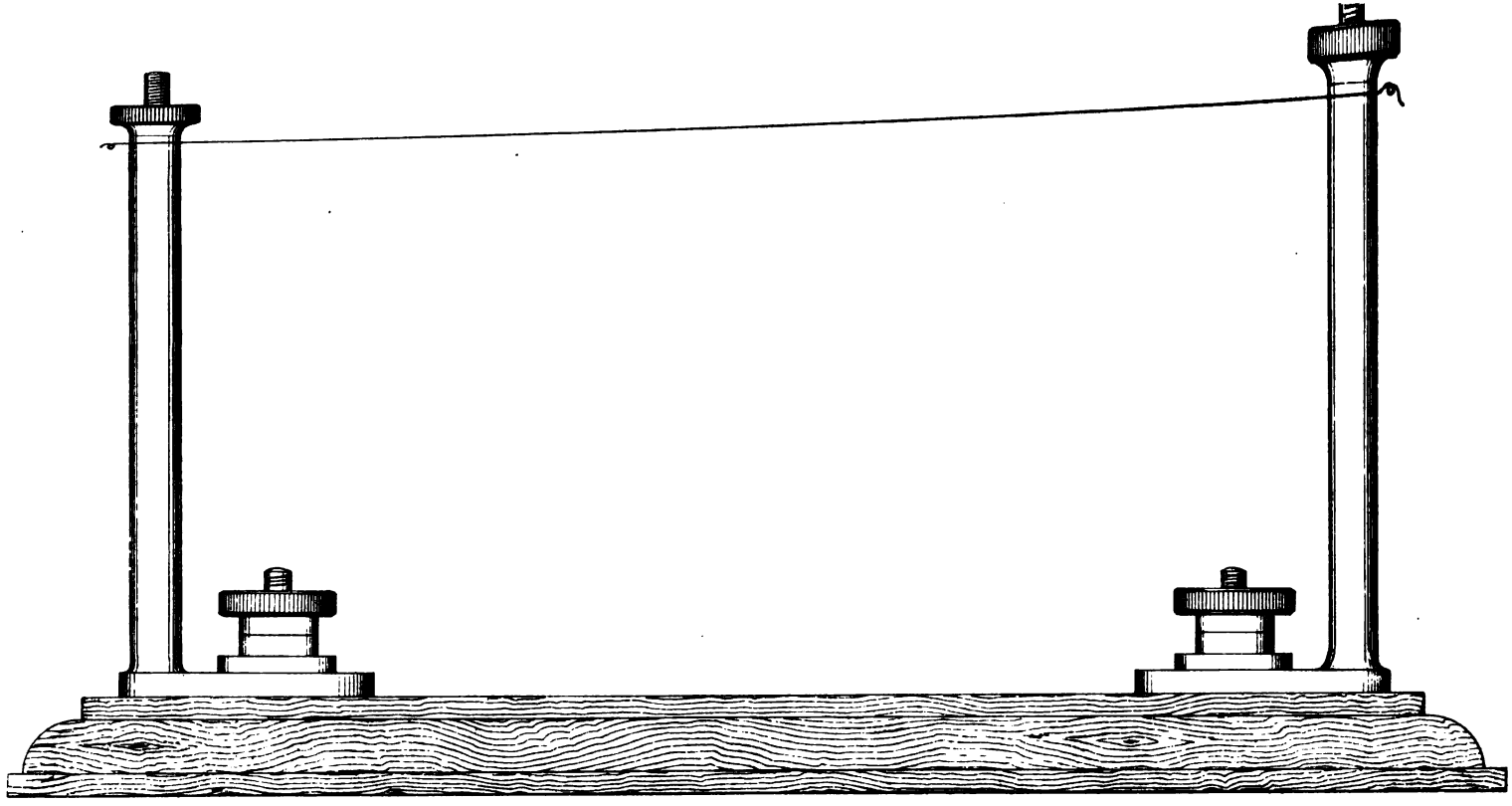

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Session IX.

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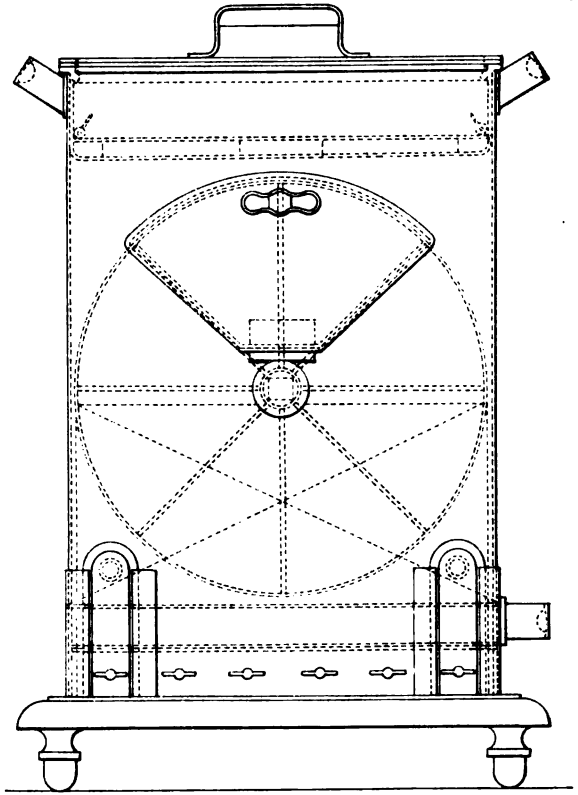
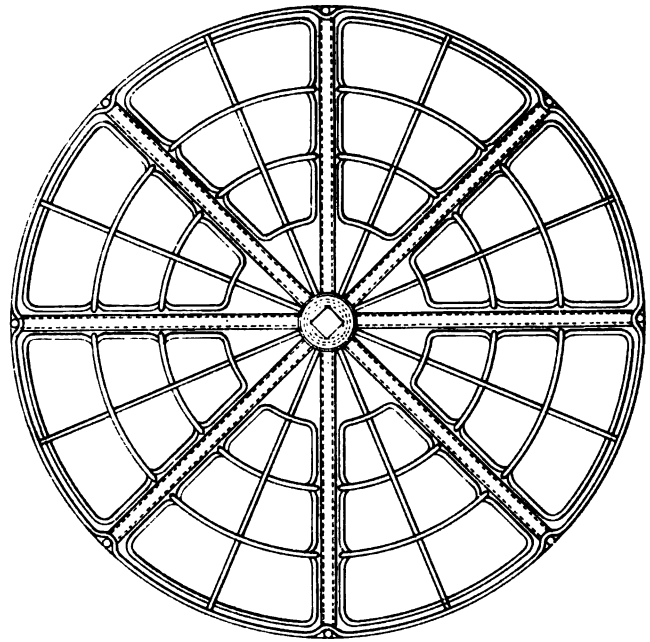
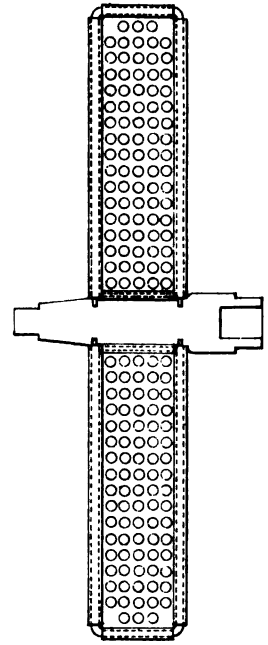
To illustrate Mr. Lewis's Paper

ELECTRIC COOKING STOVE





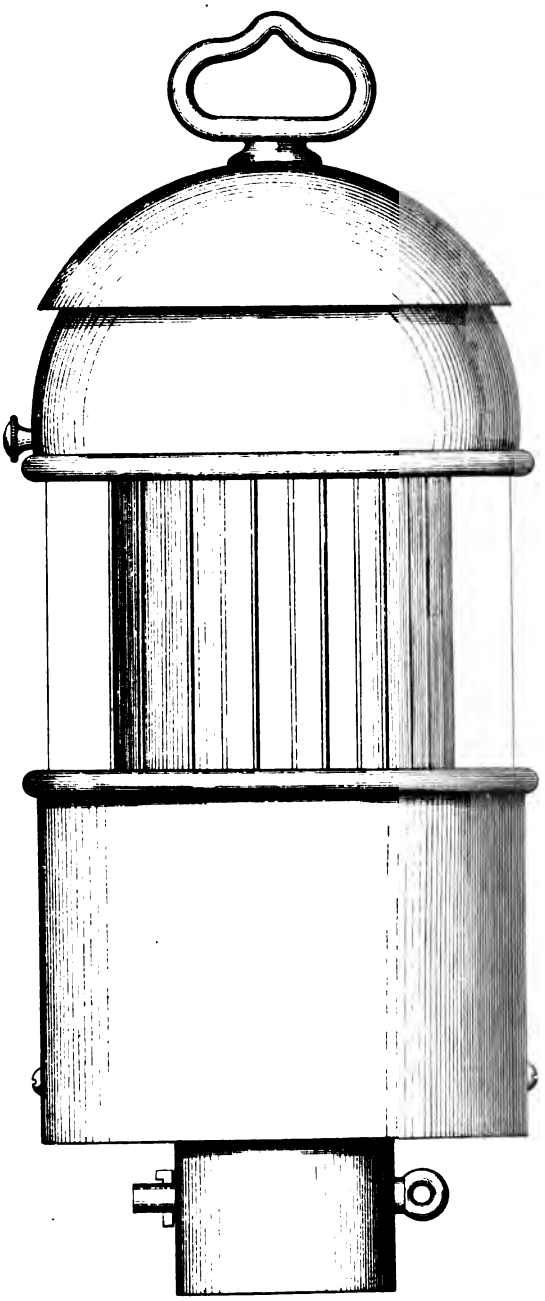


Proceedings N.E.C.I. of E&S 1892-93.
Session IX.

And^w Reid, Sons & Co^y Lithos Newcastle.

To illustrate Mr. L. Newitt's Paper on "Ships' Electrical Fittings."

Scott's Flashing Lamp.



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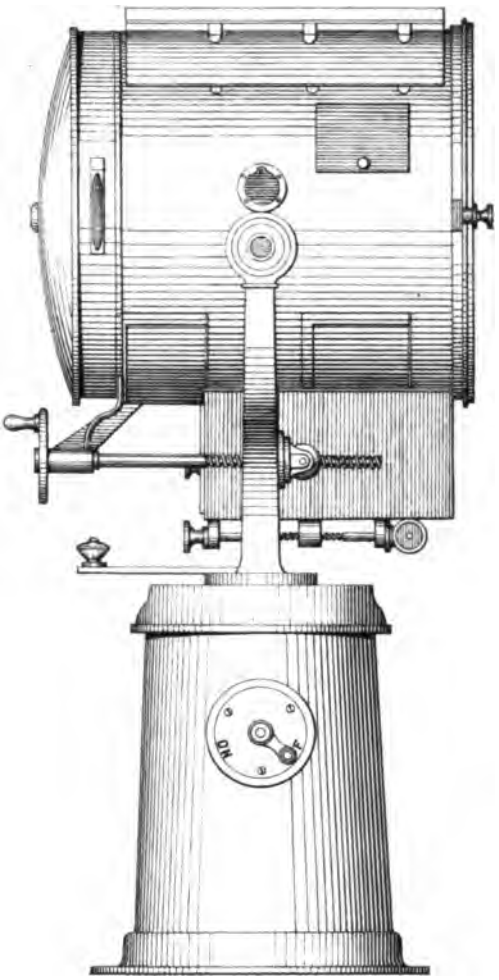
To illustrate Mr. L. Newitt's Paper on "Ships' Electrical Fittings."

SEARCH LIGHT.

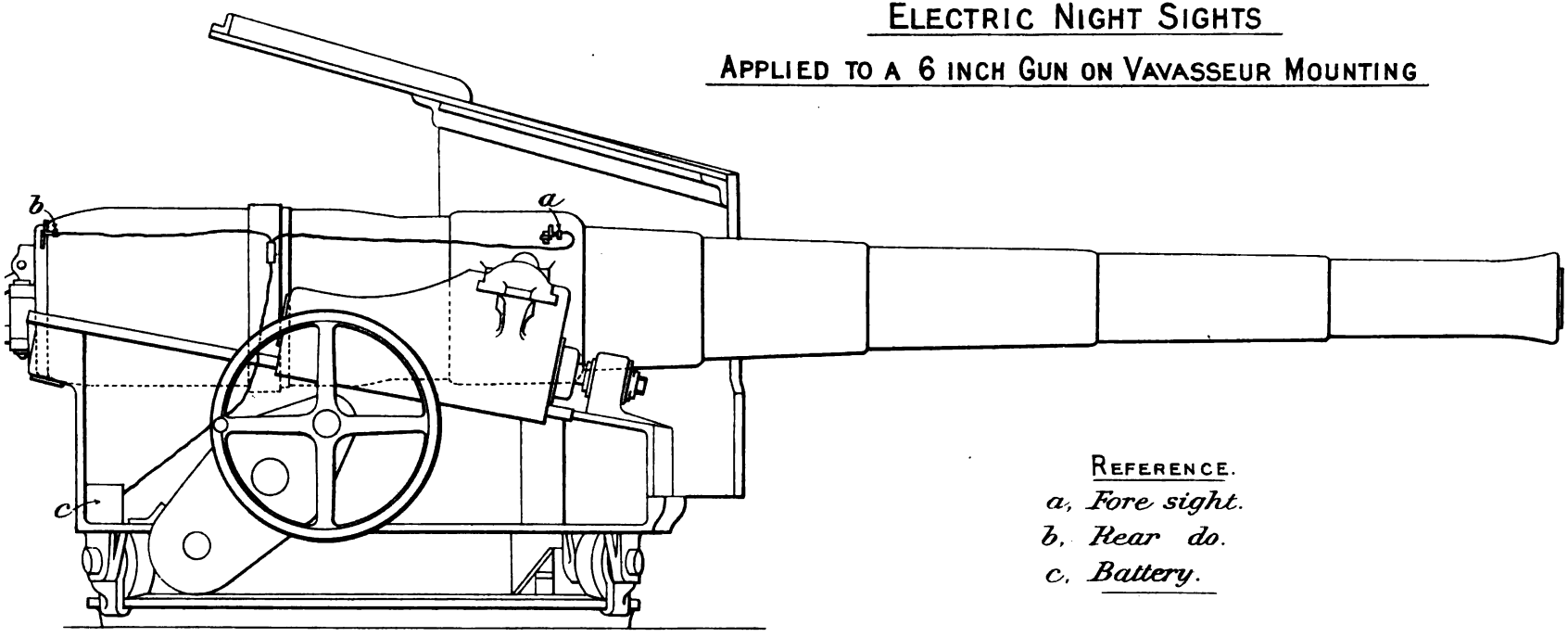


And.w Reid Sons & Co Lithos N.

To illustrate Mr. L. Newitt's Paper on "Ships' Electrical Fittings."

ELECTRIC NIGHT SIGHTS

APPLIED TO A 6 INCH GUN ON VAVASSEUR MOUNTING



REFERENCE.

a, Fore sight.
b, Rear do.
c, Battery.

And^w Reid, Sons & Co^y Lithos Newcastle

To illustrate Mr. L. Newitt's Paper on "Ships' Electrical Fittings."

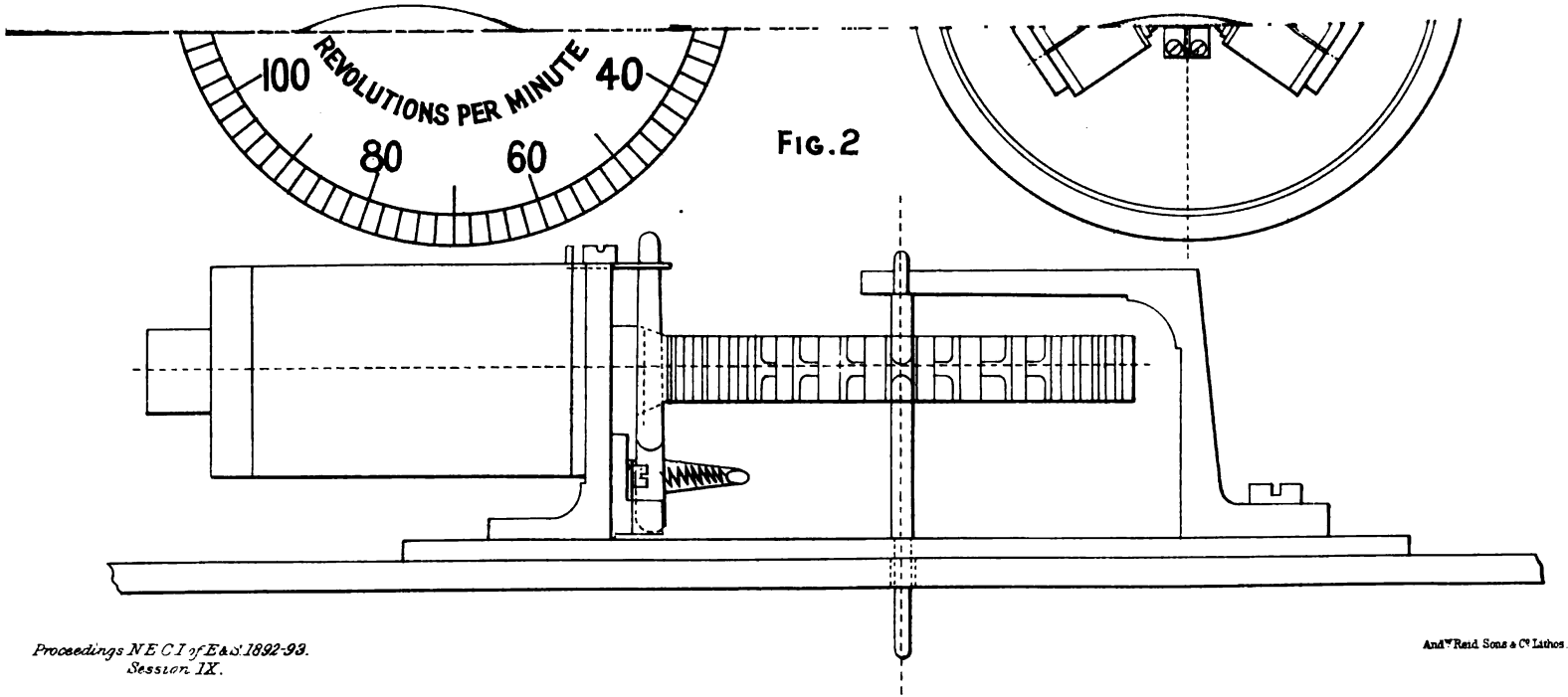


Fig. 2

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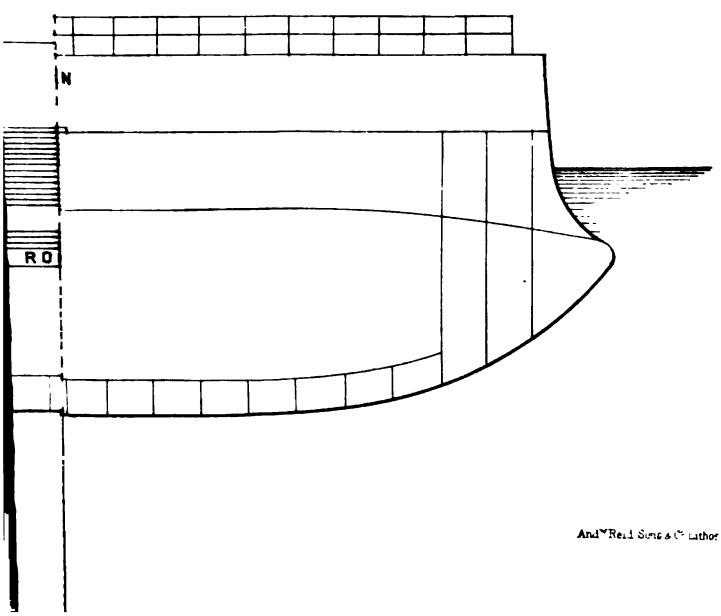
EGRAPHS ON

S.)



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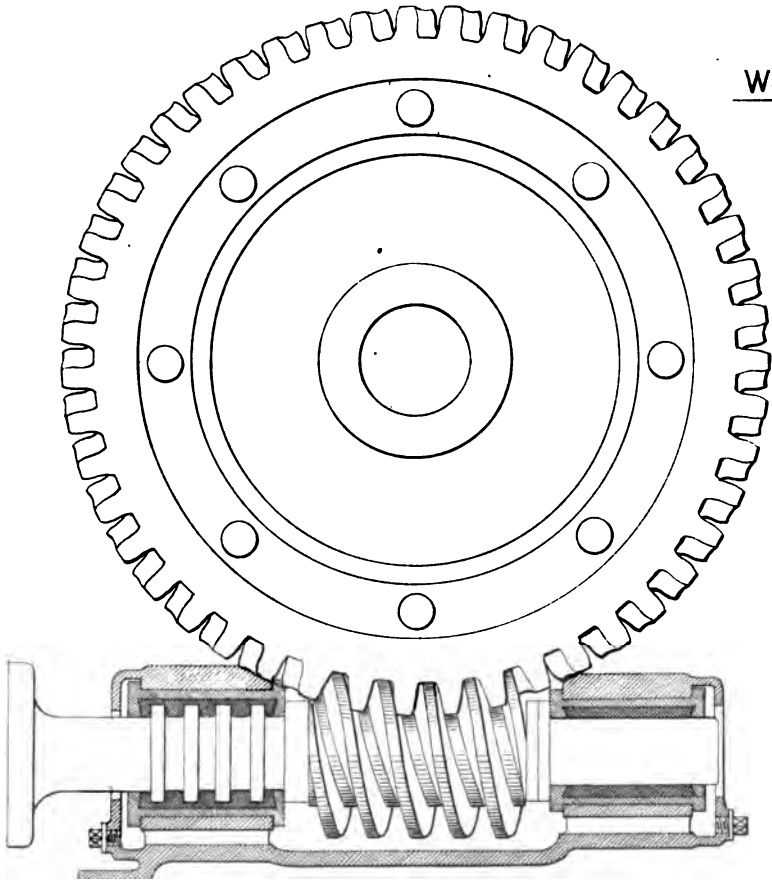
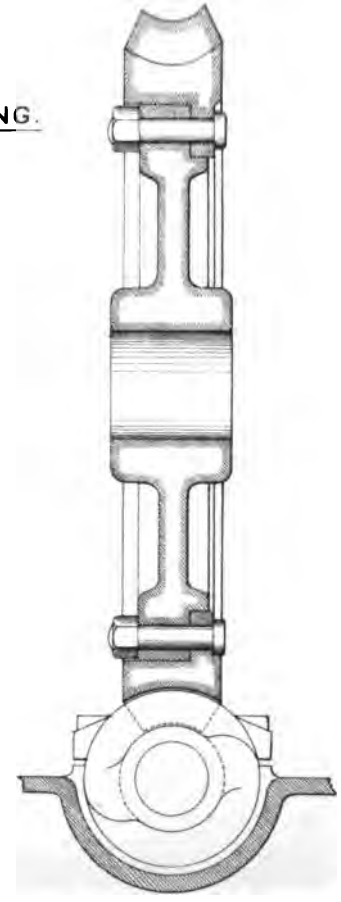
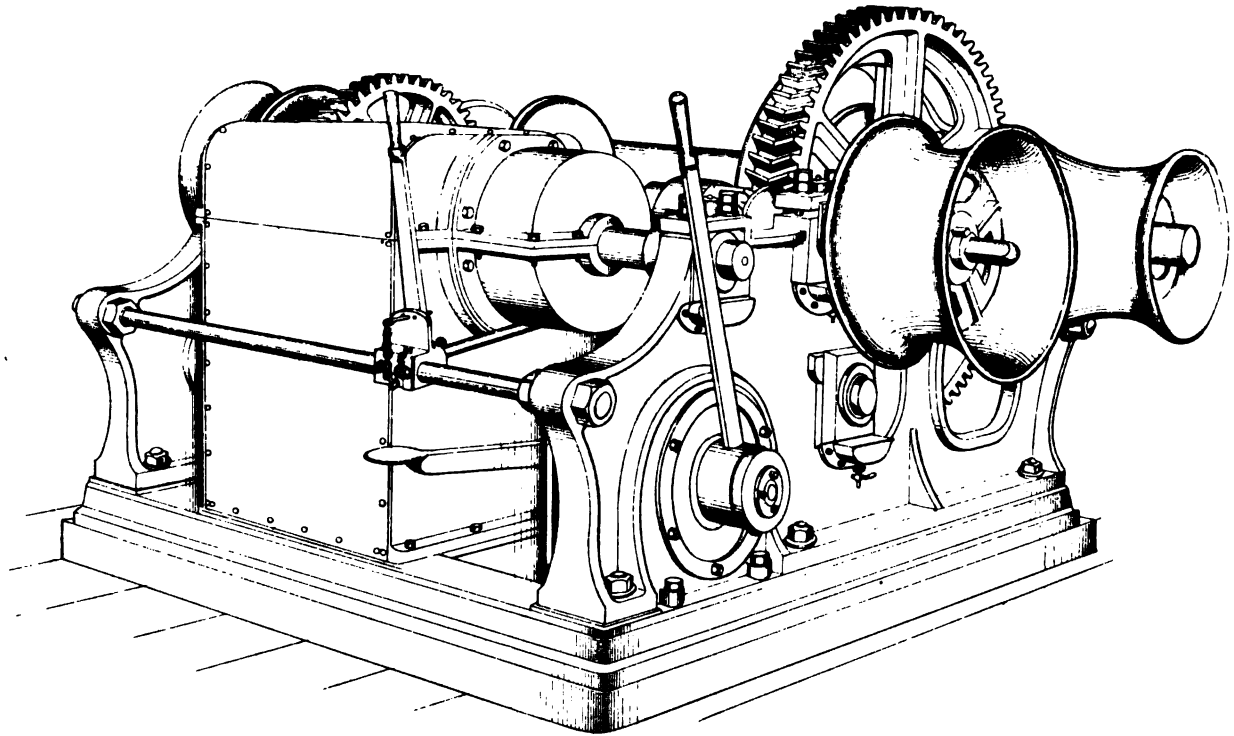
To illustrate Mr. L. Newlus Paper on [illegible]

WORM GEARING.





ELECTRIC WINCH.



Proceedings N.E.C.I. of E&S 1892-93.
Session IX.

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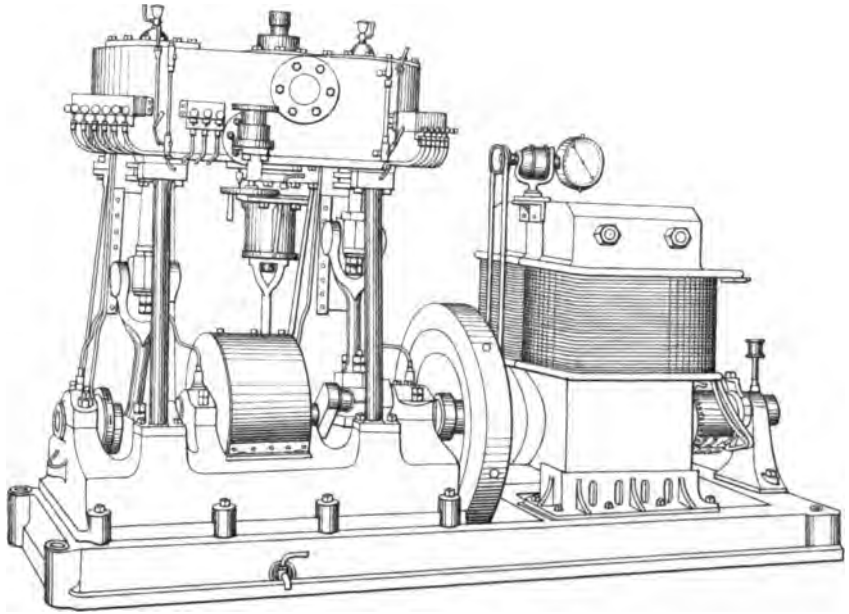
To illustrate Mr. L. Newitt's Paper on Ships Bell and Fog

SIEMENS - BELLISS COMBINATION



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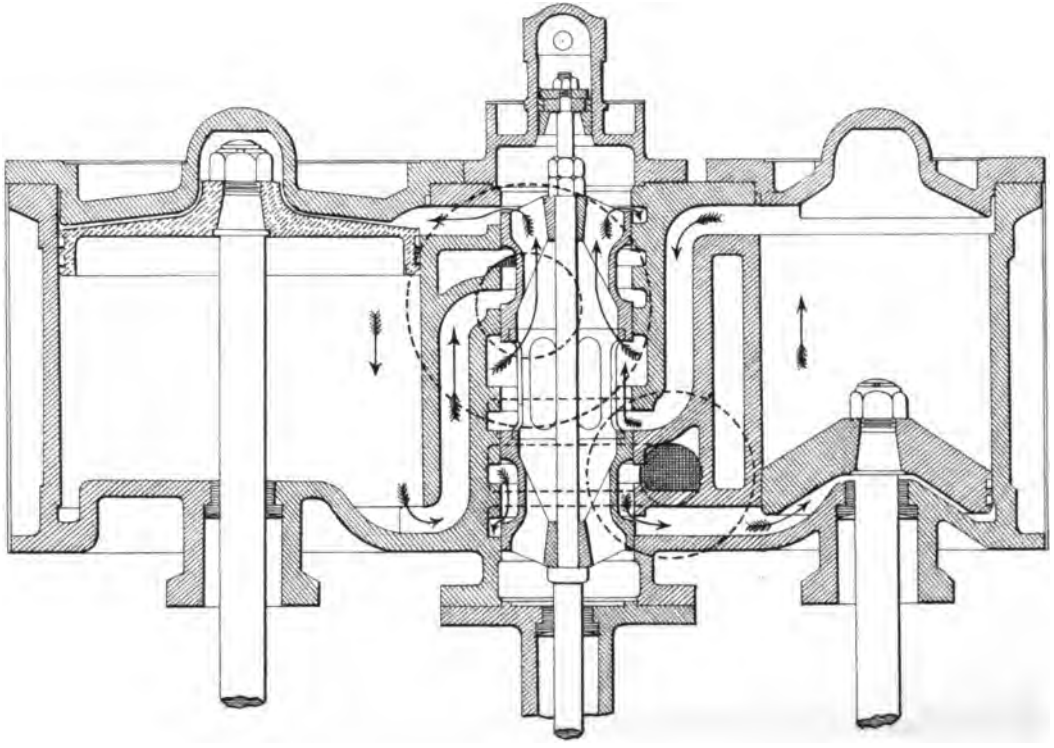
And.w Reid Sons & Co. Lithos Newcastle

To illustrate Mr. L. Newlus Paper on [illegible]

VALVE GEAR



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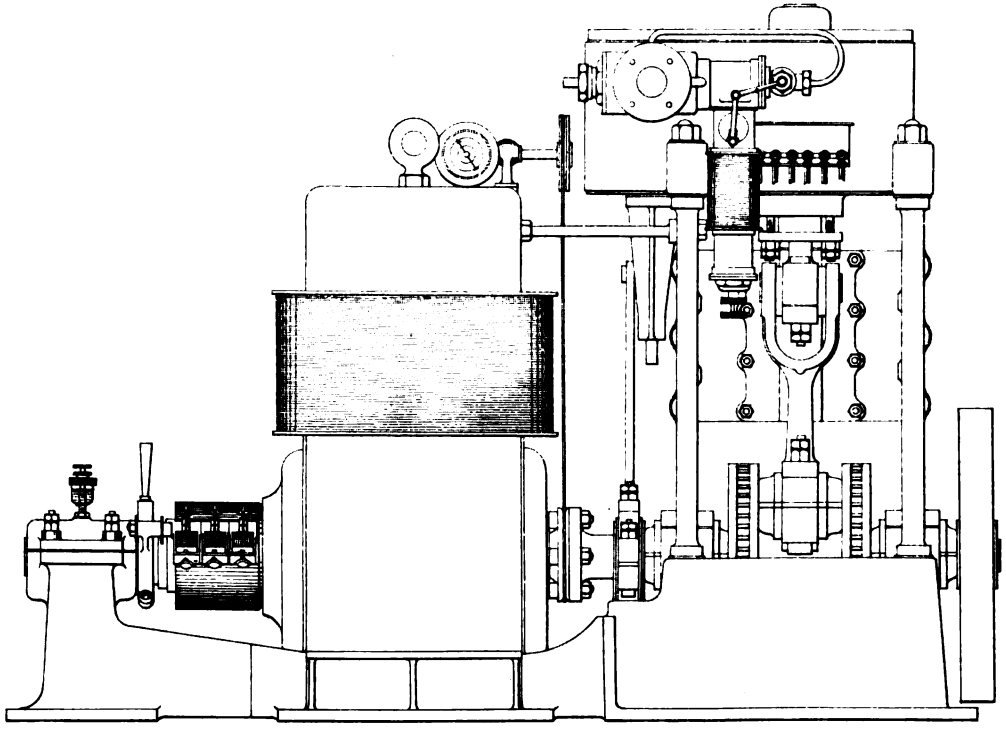
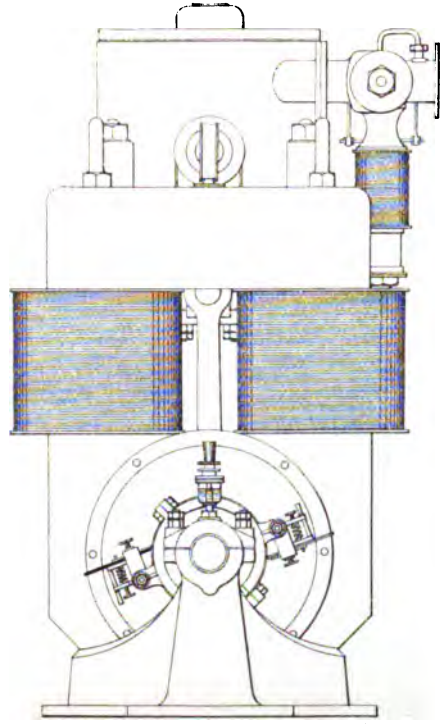
To illustrate Mr L. Newitt's Paper on "Ships' Electric Plant."

COMBINED ENGINE & DYNAMO.





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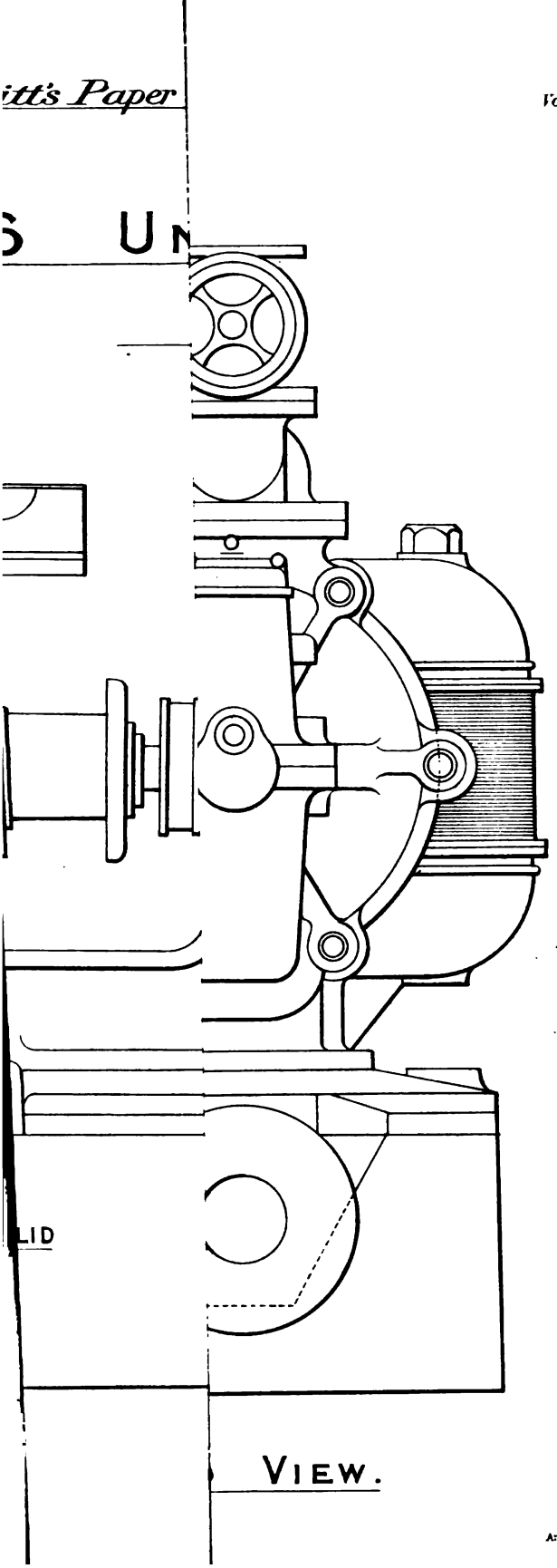

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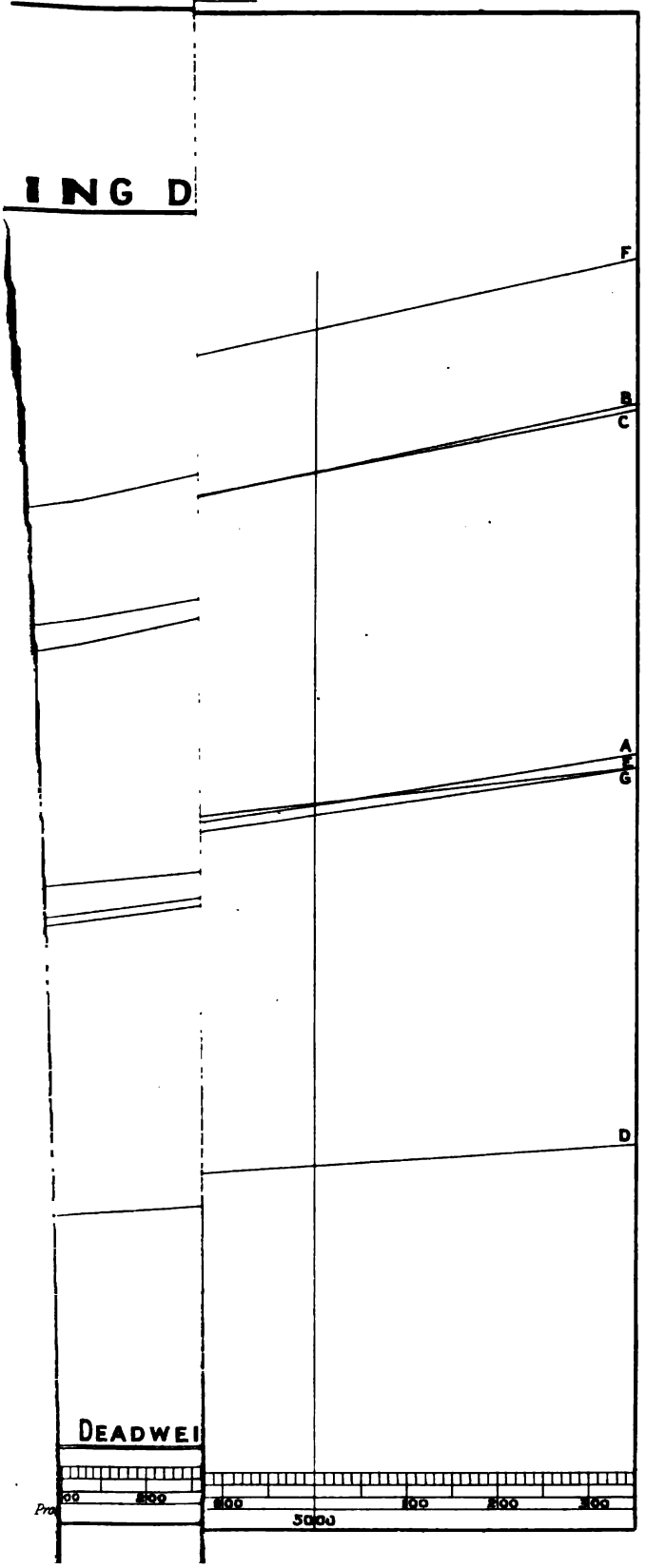
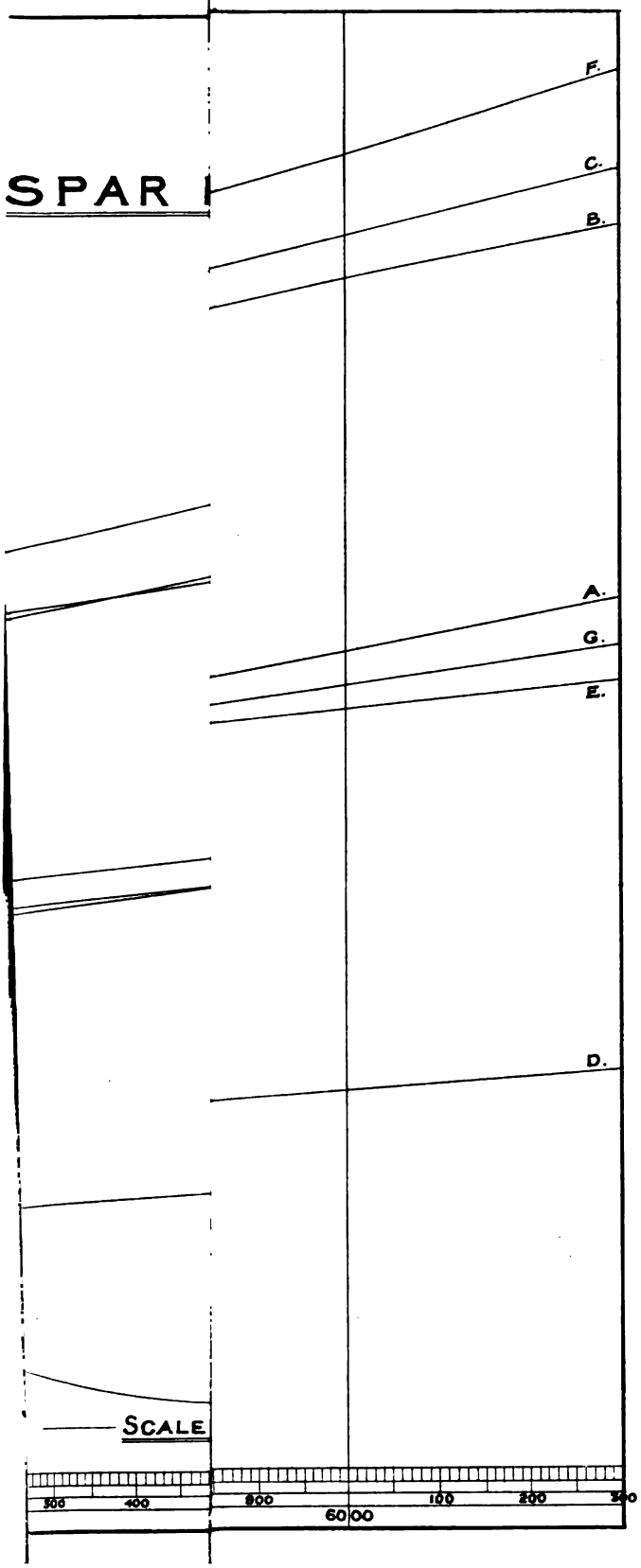
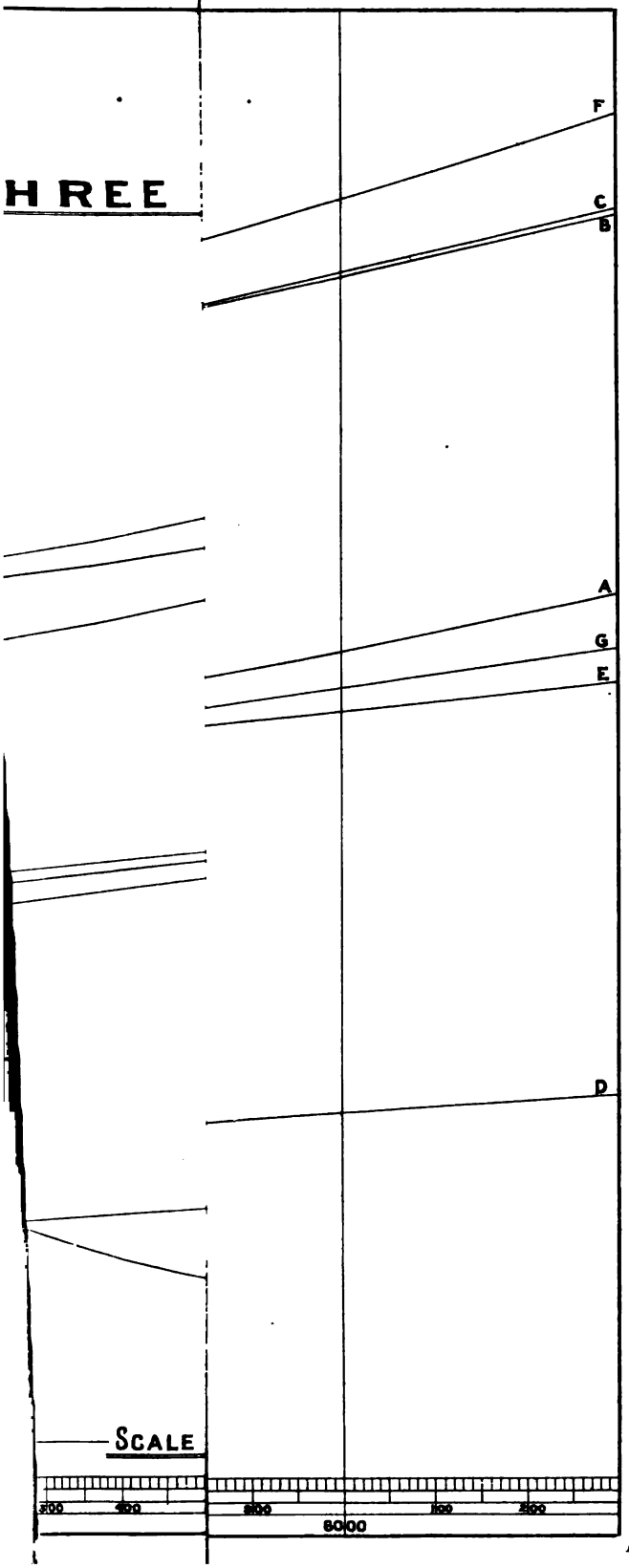


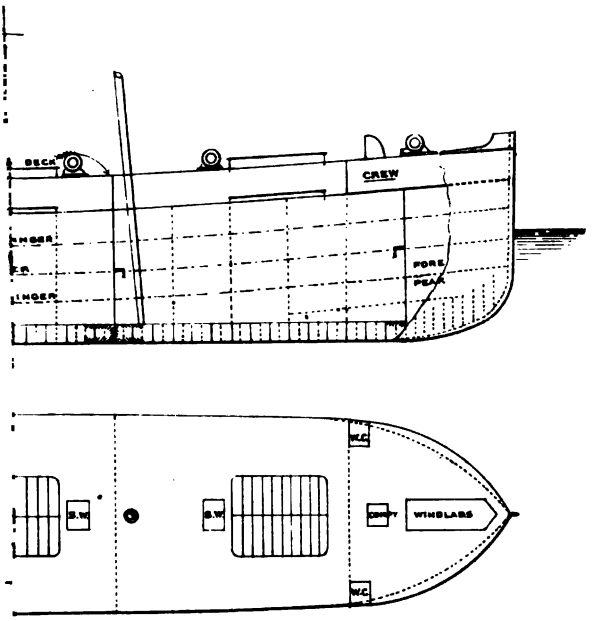
Andw Reid Sons & Co Lithos Newcastle

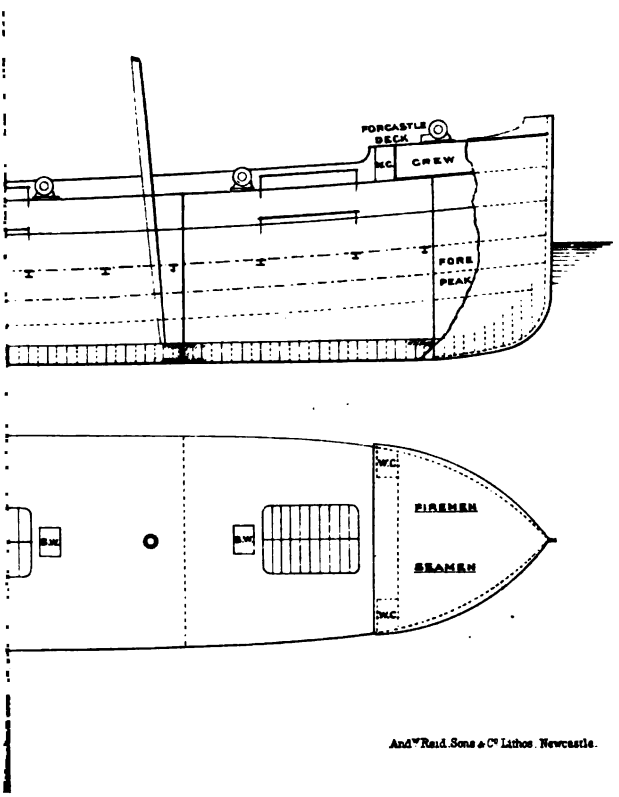


And^w Reid Sons & Co Lithos Newcastle



And^w Reid Sons & Co Lithos Newcastle.





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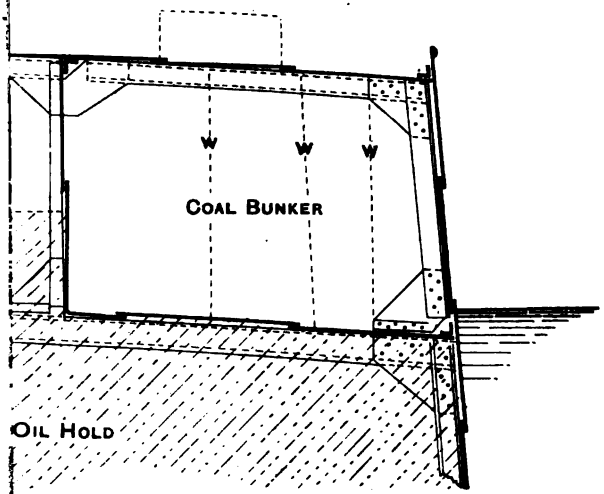
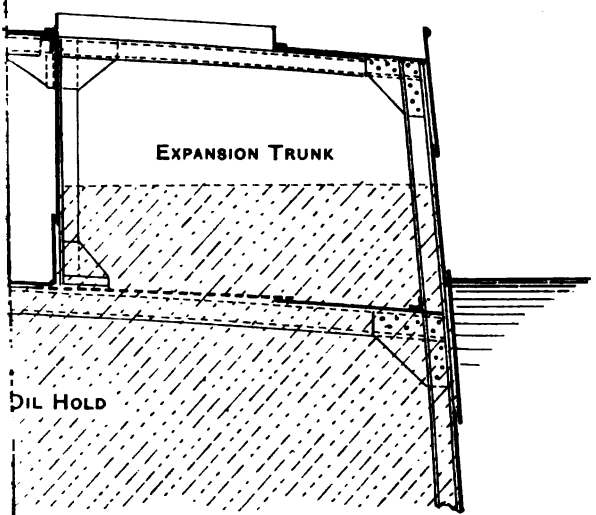
NSION TRUNKS.



AT SIDE OF SHIP.



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SPAR DECK TANK STEAMER,

310 x 40 x 29·6

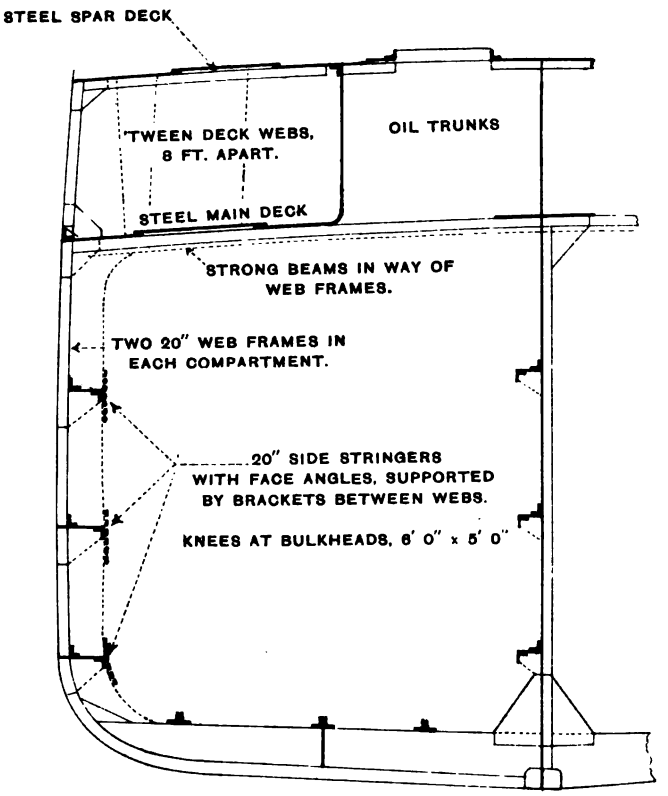


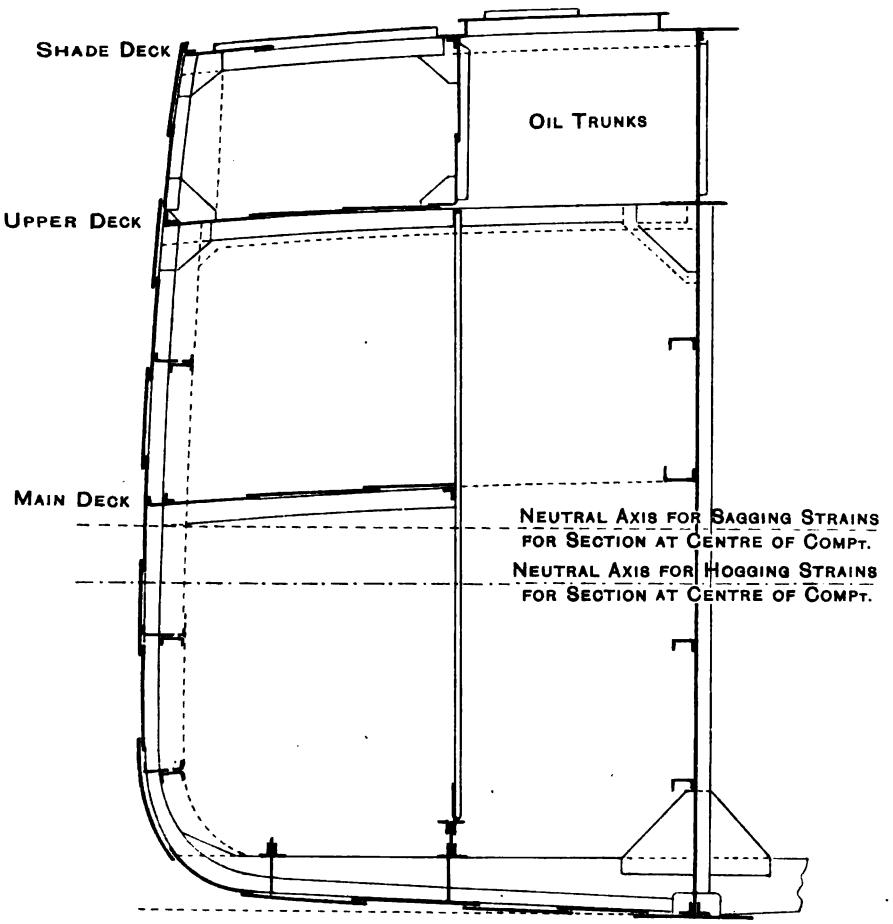
FIG. 5.

And. Reid Sons & Co. Lithos. Newcastle

To illustrate Mr. Stonard O. Kendall's Paper on "Strains on Tank Steamers."

Tank Steamer, 345′ × 45′·3″ × 35′·3″ to Shade Deck.

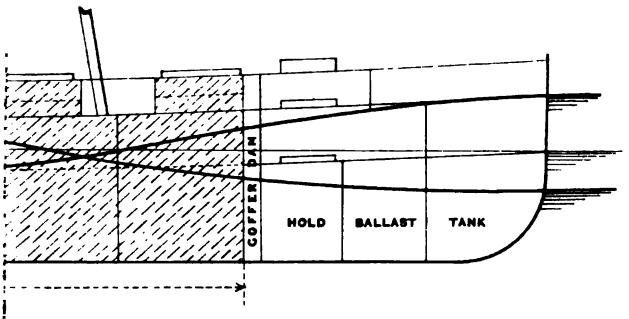
Section through Oil Compartment.



And. Reid Sons & Author Newcastle

TONS COAL.

DE DECK.



CURVE OF WEIGHT

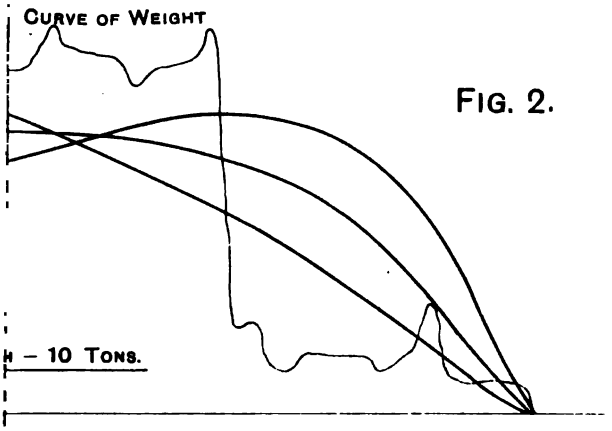


FIG. 2.

H – 10 TONS.

AGRAM OF BENDING MOMENTS

FOR ABOVE CONDITION

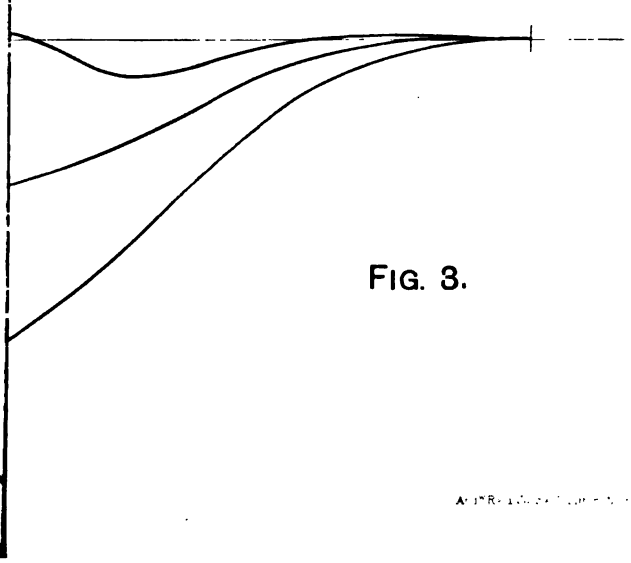
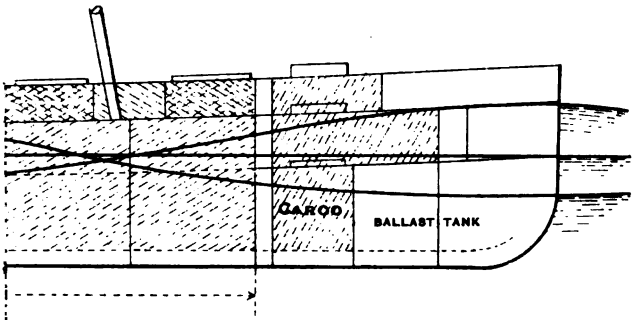


FIG. 3.

Proc

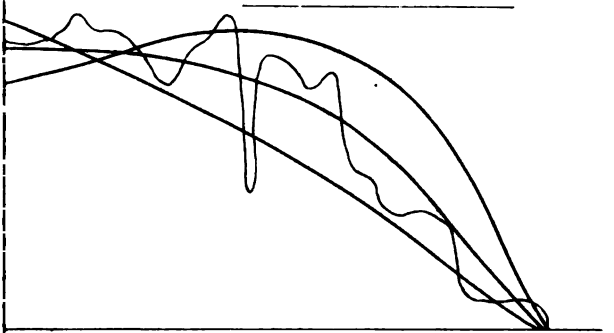
B. CONDITION.

ONS COAL.



CURVES OF WEIGHT AND BUOYANCY

FOR ABOVE CONDITION.



CURVES OF BENDING MOMENTS

FOR ABOVE CONDITION.

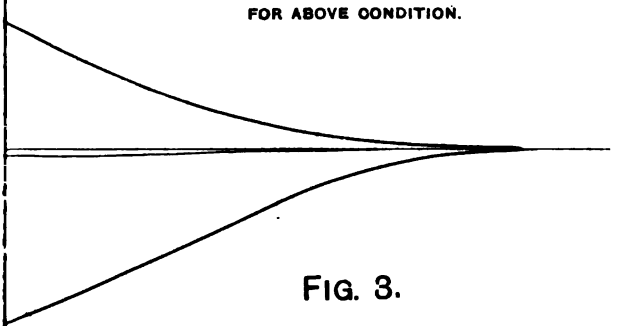
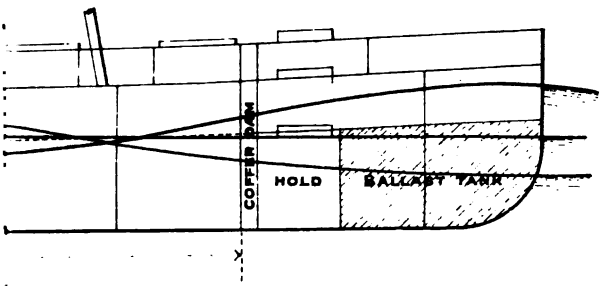


FIG. 3.

And^w Reid Sons & Co^s Lithos Newcastle

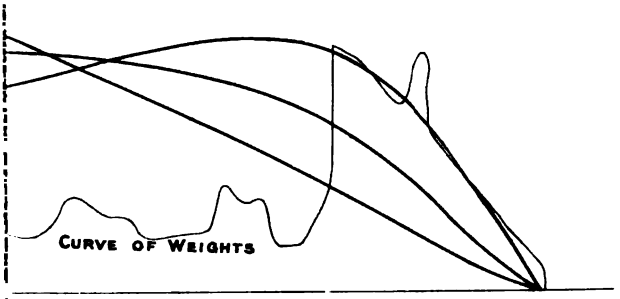
C. Condition.

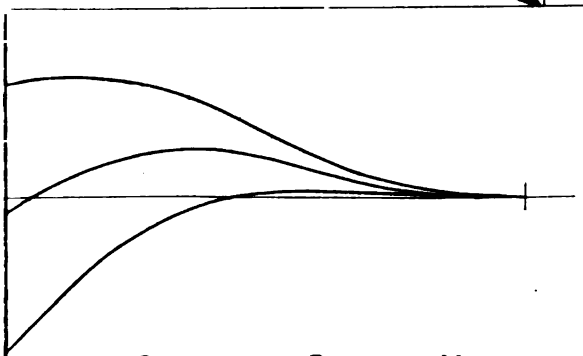
3. 500 Tons Coal.



Curves of Weight and Buoyancy

FOR ABOVE CONDITION.





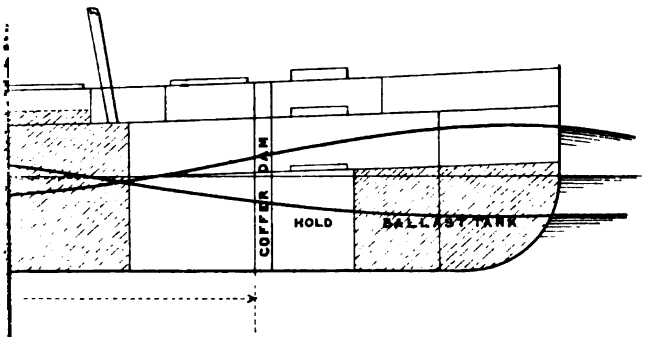
Curves of Bending Moments

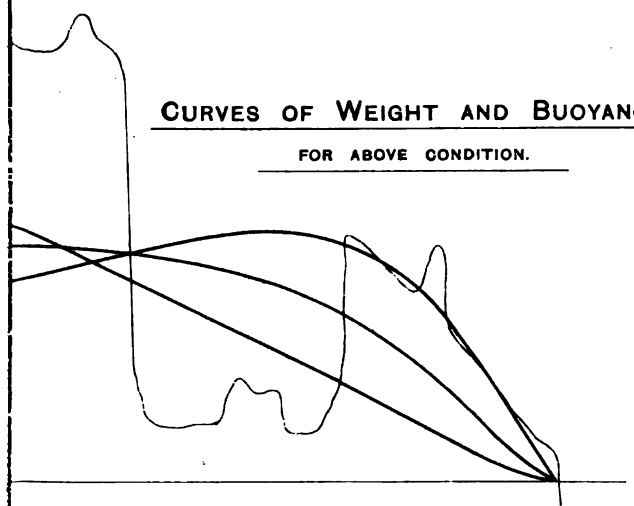
FOR ABOVE CONDITION.

And^w Reid Sons & Co Lithos Newcastle

D. Condition.

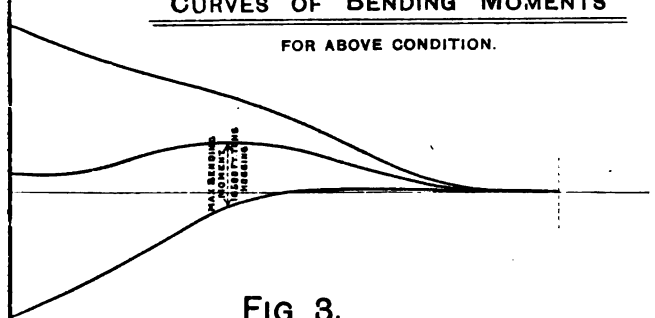
NKS, 500 Tons Coal.





Curves of Weight and Buoyancy

FOR ABOVE CONDITION.



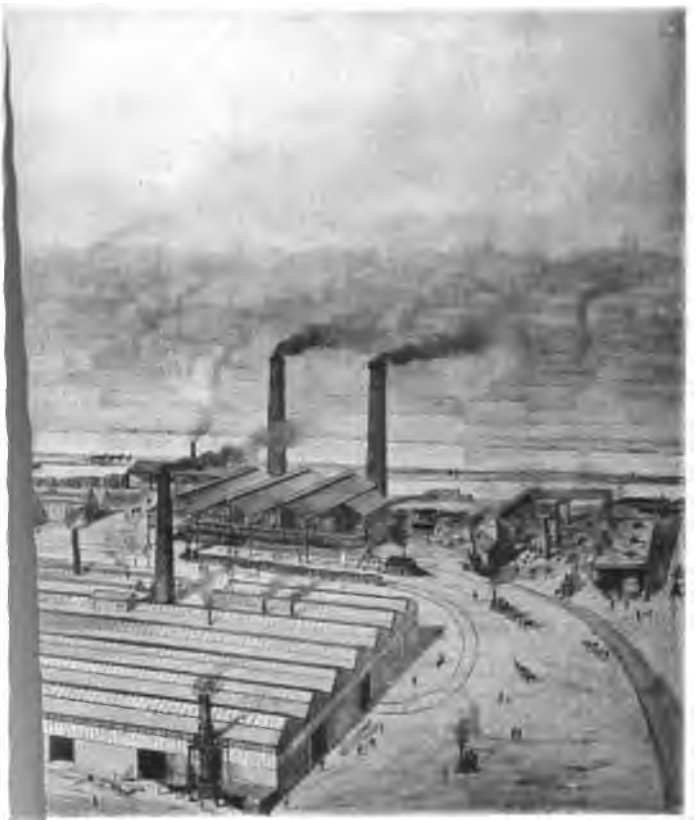
Curves of Bending Moments

FOR ABOVE CONDITION.

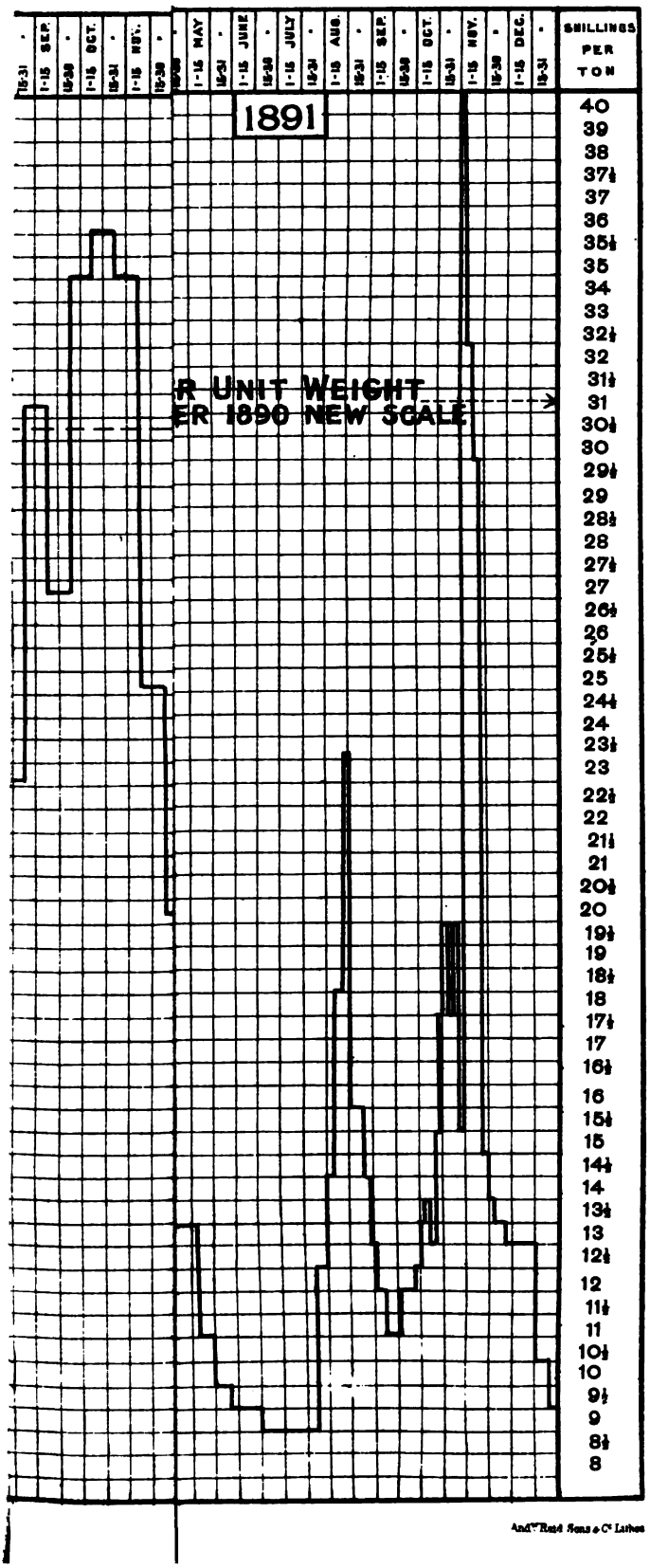
Fig. 3.

And^w Reid Sons & Co^s Lith. Newcastle

...eds Forge Company's Works.



And^w Reid Sc. ... Lithos Newcastle



And^w Reid Sons & Co^y Litho Newcastle

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